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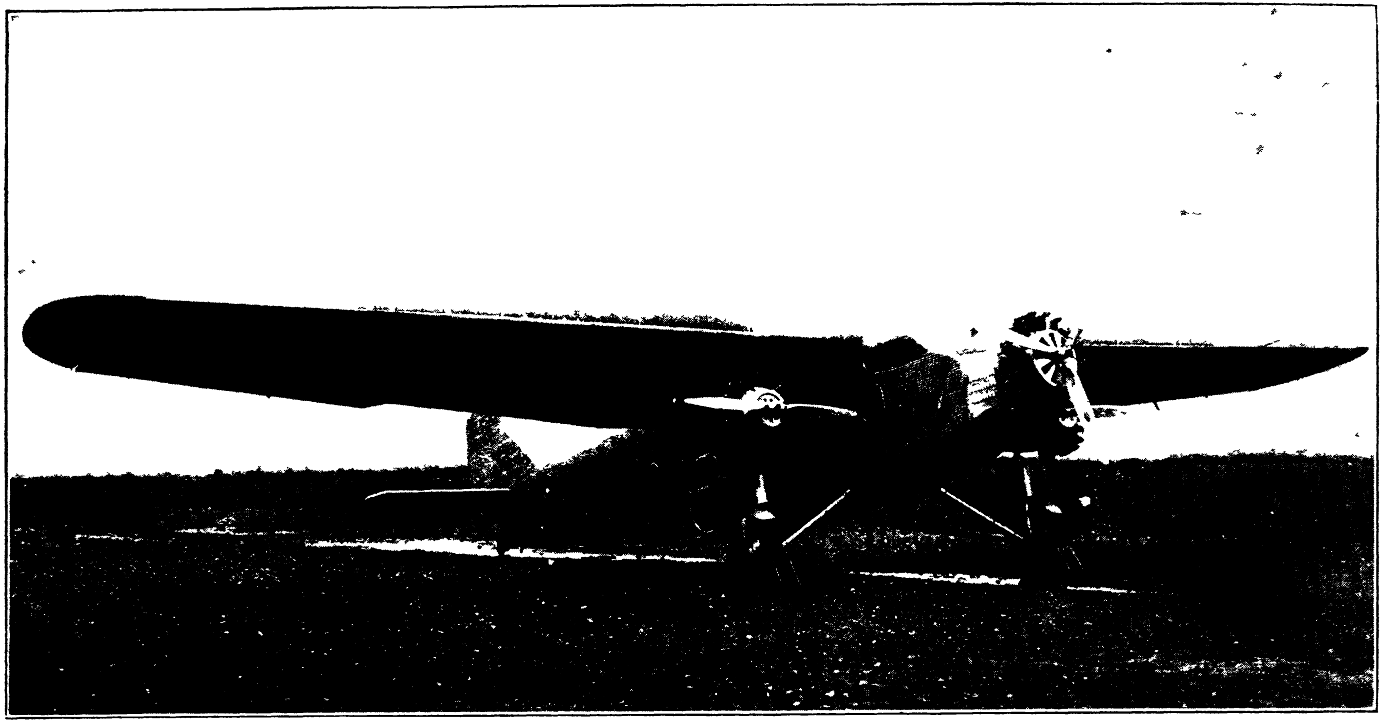

"THE FLOYD BENNETT," THE FORD MONOPLANE EQUIPPED WITH ONE WRIGHT CYCLONE AND TWO WRIGHT WHIRLWIND ENGINES, WHICH COMMANDER R. E. BYRD IS USING IN HIS EXPLORATIONS IN THE ANTARCTIC

Automobile Engineering

A Reading Course and General Reference Work for

Auto-Mechanics, Chauffeurs, and Owners, Covering the Construction,
Care, and Repair of Pleasure Cars, Commercial Cars, and
Motorcycles, with Special Attention to Ignition,
Starting, and Lighting Systems, Aviation
Engines, Welding, Etc.

Prepared by a Staff of
Automobile Experts, Designers, and Consulting Engineers

Over Fifteen Hundred Illustrations
Six Volumes

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Grateful acknowledgment is here made also for the invaluable cooperation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the construction, operation, and repair of Automobiles, Aviation Engines, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies; also to the National Automotive Service who publish the National Service Manual which gives the wiring diagrams of all Automobiles released from 1915 to date together with complete information and necessary instructions for the care, adjustment, trouble shooting, and repair of all the electrical equipment.

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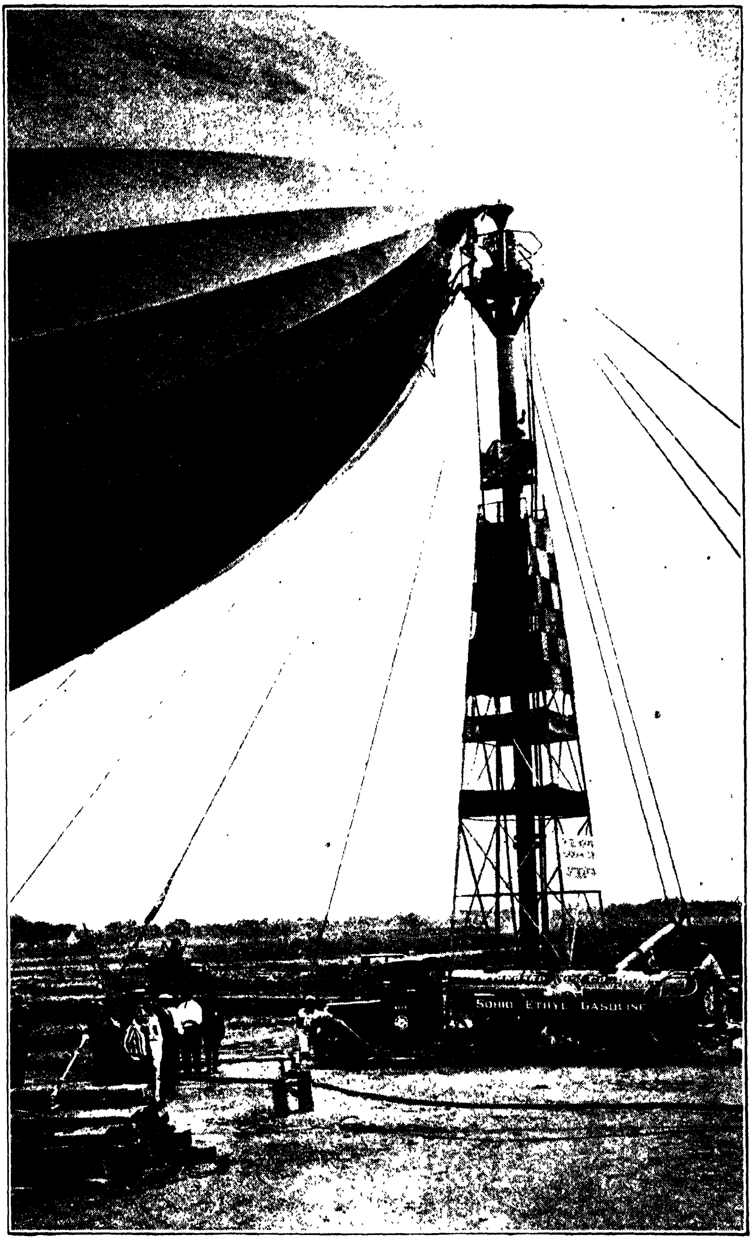

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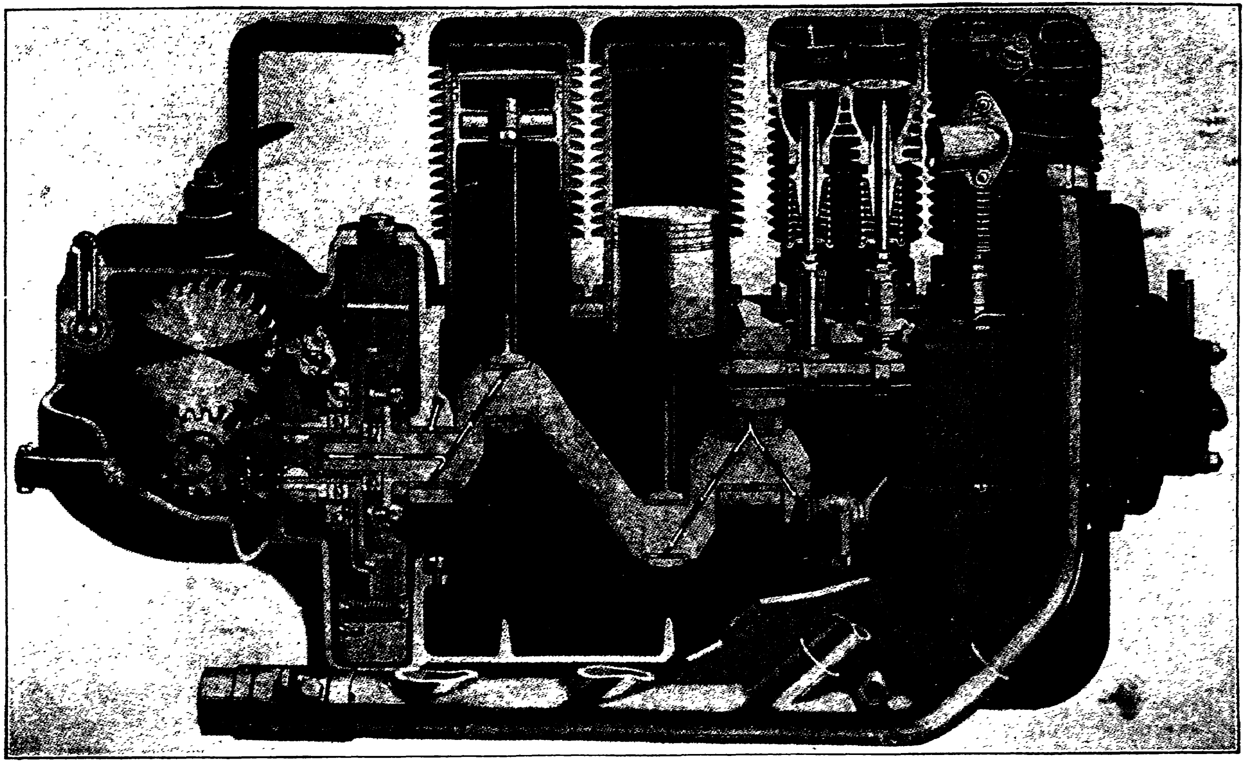

SECTIONAL VIEW OF HENDERSON MOTORCYCLE ENGINE

Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago

Foreword

THE period of evolution of the automobile does not span many years, but the evolution has been none the less spectacular and complete. From a creature of sudden caprices and uncertain behavior, it has become today a well-behaved thoroughbred of known habits and perfect reliability. The driver no longer needs to carry war clothes in momentary expectation of a call to the front. He sits in his seat, starts his engine by pressing a button with his hand or foot, and probably for weeks on end will not need to do anything more serious than feed his animal gasoline or oil, screw up a few grease cups, and pump up a tire or two.

¶ And yet, the traveling along this road of reliability and mechanical perfection has not been easy, and the grades have not been negotiated or the heights reached without many trials and failures. The application of the internal-combustion engine, the electric motor, the storage battery, and the steam engine to the development of the modern types of mechanically-propelled road carriages has been a far-reaching engineering problem cf great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced driver, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded.

¶ The refinements in the ignition, starting, and lighting systems have added greatly to the pleasure in running the car. Altogether, the automobile as a whole has become standardized, and unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

¶ Notwithstanding the high degree of reliability already attained, the cars, as they get older, need the attention of the repair man. This is particularly true of the cars two and three seasons old. A special effort, therefore, has been made to furnish information which will be of value to the men whose duty it is to revive the faltering action of the engine and to take care of the other internal troubles in the machine.

¶ Special effort has been made to emphasize the treatment of the Electrical Equipment of Gasoline Cars, not only because it is in this direction that most of the improvements have lately taken place but also because this department of automobile construction is least familiar to the repair men and others interested in the details of the automobile. A multitude of diagrams have been supplied showing the constructive features and wiring circuits of the majority of the systems. In addition to this instructive section, particular attention is called to the articles on Welding, Shop Information, and Electrical Repairs.

¶ The great stimulus enjoyed by the aeronautical industry since the crossing of the Atlantic by Lindbergh and the conquering of this and other oceans by later pilots has resulted in a great number of men seeking training in the ground or engine work in that field. Most of the airplane engine men are recruited from the automobile field. The constructional features of the modern airplane engine are fundamentally the same as for the automobile engine. Standards of workmanship are the same. The best only is acceptable. There are certain differences in standard clearances allowed in repair work. In the main, however, the thoroughly trained and expert auto-mechanic may expect to find success in the airplane engine field if he devotes the same effort to it which he had to give to the automobile work to earn a name as an expert auto-mechanic. It likewise holds true that the beginner in either field must make a study of the underlying theory of the construction of the automotive power plants and he must develop skill and knowledge of proper methods of repair. These volumes are devoted to imparting the information on theory of construction and methods of repair which will insure authentic knowledge of all phases of automotive work.

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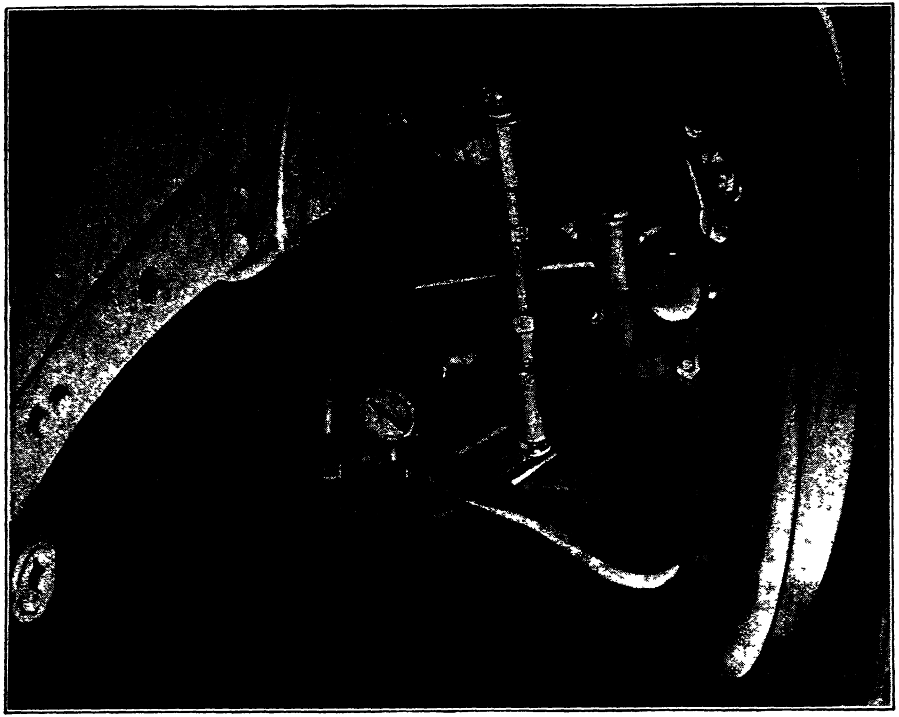


BENDIX BRAKES OF THE LEVER TYPE APPLIED TO A FRONT WHEEL OF THE STUDEBAKER "PRESIDENT EIGHT"

BRAKES

Even the two-wheel brakes of yesteryear are permitted on our highways simply because of the fact that the drivers of cars so equipped are mostly of the old school and know the limits of their equipment.

Service methods and service problems with two-wheel brakes are relatively simple when compared to the four-wheel problems. In the past the problem was one of getting the car to run, rather than finding ways to stop it from its top speed of thirty to forty miles per hour.

When a car failed to brake properly, the owner adjusted his brakes wherever he happened to be, just as he would get out his tools and change a plug or grind a valve, if such work needed doing.

At a somewhat later point in the history of the industry, two-wheel brakes were developed to the point where, with reasonable care, a car could be driven for a season without any brake adjustments. When the car did come into the shop, the mechanics would reline, run-in, and adjust the brakes so that they were good for another season of what was then accepted as satisfactory brake performance. The two-wheel brakes were not so difficult to equalize and the stopping test on the garage floor or the street was the test of their efficiency. Two black marks left from two scuffed tires told the results. For the demands of that day, the methods were satisfactory.

In those days there were no problems of the 40-60 and the 50-50 load. The problem of steering was not a factor. Out-of-round drums were not worried about, as long as they were merely egg-shaped and not square. Exclusion of dirt, Fig. 1, was of minor importance. Four-wheel brakes brought a score of new problems. Not the least of these is the feeling, in the minds of the public, of safety at all speeds, which has been built up by the motor manufacturers in their national advertising.

New Service Equipment and Methods. Snappy engines, rapid acceleration, four-wheel brakes, and rapid deceleration, as depicted in Fig. 2, are the standards of mechanical performance the car owner is most concerned in. Unfortunately he is less concerned about the stopping part than he should be.

The rather simple two-wheel brake design has given way to the four-wheel brakes of complicated design. Two-wheel brakes gave rise to no very serious problems in science and mathematics. Four-wheel brakes have brought about dozens of engineering problems which are difficult of solution. Every service man remembers the four-wheel brake stories of buckling cars, overturned cars, skidding cars, disconnected front-wheel brakes, locked front wheels, and cars ruled off the road by state law. The stories were of infinite variation, but four-wheel brakes are on all the cars now. It is true that design is becoming standardized. The old two-wheel design is fast losing ground as an item to be modified, so as to apply it to the front wheels as well as to the rear.

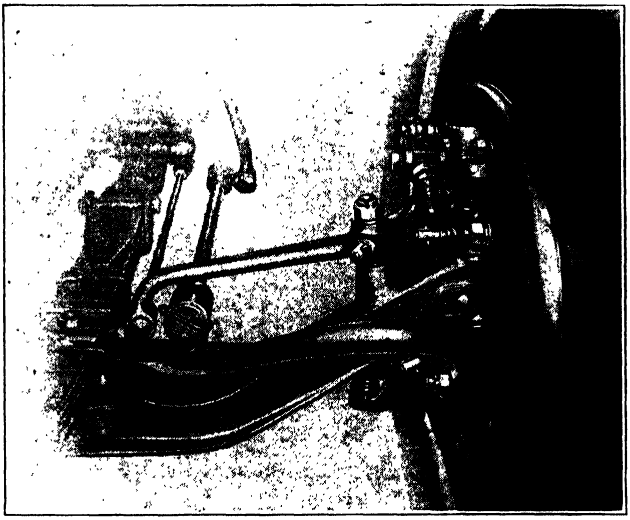


Fig. 1. Chevrolet Front-Wheel Brakes Are Enclosed to Exclude Road Splash

Factories quickly found that special equipment was necessary to turn out cars which would brake properly. It was not enough to design special four-wheel brake jobs and then trust that they would be equalized when set up to certain predetermined settings. It did not work. In many cases four-wheel brakes fell into disrepute for this very reason.

Necessity again proved the mother of invention and presently four-wheel brake testing equipment made its appearance on the end of the assembly lines, with the result that four-wheel brakes were properly set when the car left the factory and four-wheel brake performance was the marvel it is.

Scientifically-designed brake-testing equipment is now available for service shops as well as for the factories. This equipment is available in many styles. It ranges in price from a few dollars up to several thousand, but science has played its part in the design of even the most simple and least costly. No shop featuring brake service should be without some form of test equipment which records braking effort in an easily understood and real fashion, so that comparisons and equalization may be effected.

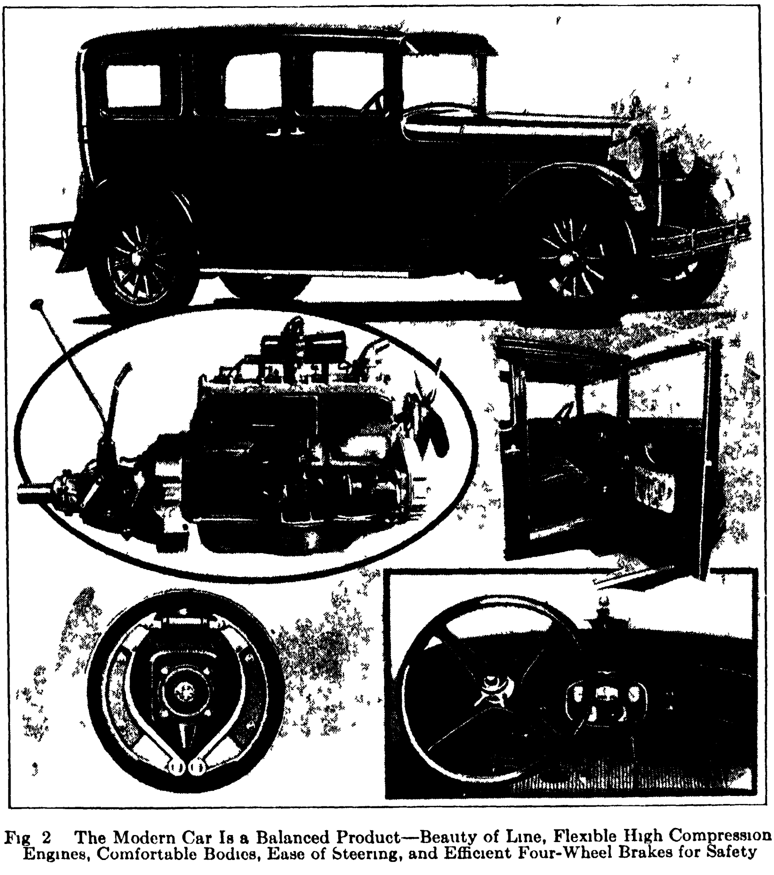


Fig 2 The Modern Car Is a Balanced Product—Beauty of Line, Flexible High Compression Engines, Comfortable Bodies, Ease of Steering, and Efficient Four-Wheel Brakes for Safety

There are on the market today a number of cars with stamped brake drums. These are sometimes applied without any machining operation, with the result that the drums are not round. Perhaps production methods demand the use of this method, but it is regrettable that some of these drums could not be made of heavier stock to permit of proper machining operations when it is desired to give the car owner a real brake job.

There are on the market and in use in many service stations some very splendid brake-drum machine tools. Car owners want perfect brakes. The service man is equipped for giving the car owner what he wants, but in some cases the drums are too thin to stand machining. The only remedy in such cases is to put the customer to the expense of drums, which are heavy enough that, when they have been installed on the wheels, the entire assembly may be mounted in the machine and the drums brought to a true surface.

PREPARING CAR FOR BRAKE TEST AND ADJUSTMENT

It is useless to attempt to adjust brakes or make an exact test unless the brake mechanism is in proper operating condition. The car should be placed in position where the brake rigging can be carefully inspected. The use of a free-wheel car lift is quite an aid in this work.

Mechanical Systems. Test the brake pedal action and the spring return. Have the helper work the pedal while a careful inspection is made of each individual brake action. In similar manner check up on the brake linkage. Check the bushings or bearings. Check the toggle and cam action. Check the flexible shafts, clevis pins, equalizer action, stop screws, etc.

If there is evidence of lack of oil, it is best to remove the clevis pins and disconnect the parts or apply penetrating oil and work the parts until they are free. Next clean the parts and apply lubricating oil or grease as the need may be, then proceed to reassemble and adjust.

Hydraulic System. See that the flexible hose connections are all in good repair. Check and lubricate all spring action. Inspect the main and wheel cylinders for leaks. Check up on the tube fittings. See that the supply tank has a proper quantity of brake fluid. See that the system has the proper amount of fluid in it. If it has been giving any trouble, bleed it to remove any air pockets.

Brake Leverage. After all the parts are working freely, the next step is to see that all levers or cams are set properly for positive action. A lever should never pass center more than a slight amount.

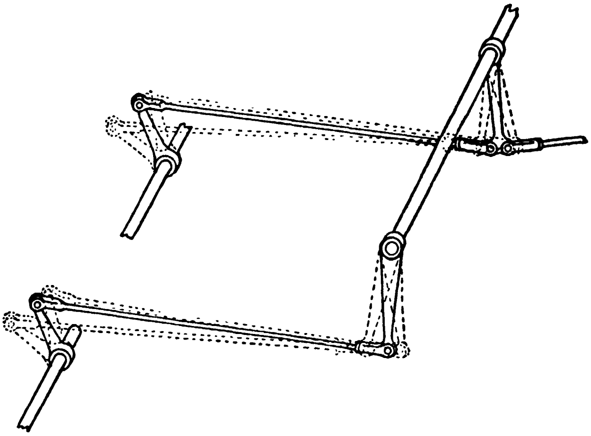


Fig. 3. Solid Lines Indicate the Proper Lever Setting When the Brakes Are in the "Off" Position
Dotted Lines Indicate Improper Setting When the Levers Are Set Too Far Ahead or Too Far Back

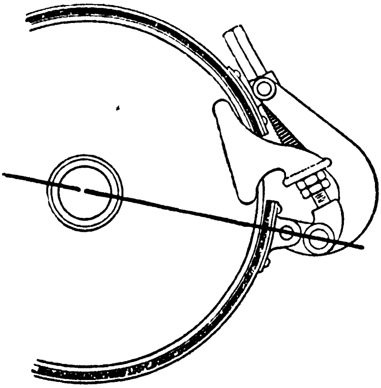


Fig. 4. Lever Position for External Contracting Brakes
Note the center line running through the center of the axle and through the center of the brake pins, connecting the lever to the brake band. Both sides should be the same.

It should start back of center and advance to center position. Usually this means a vertical or perpendicular position when brakes are fully applied. Refer to Figs. 3 and 4. By adjusting the brake bands or other parts properly, the levers can be brought into proper position.

Brake Lining Clearance. The clearance between the lining and the drum must be properly set. This is perhaps the first step in adjusting brakes. Many mechanics will set up the bands with reference to the brake drum and the cam or toggle levers at the same time and then work from that adjustment to the pedal, through the rest of the brake linkage.

External contracting bands must be given more clearance than is necessary for internal expanding shoes. The reason for this is the expansion which occurs when the brake drums are heated in service. Where large drums are used, this expansion is very great and results in a tendency to lock the wheels. It is for this reason that it is necessary, in many cars having the external contracting brakes, to let up on the pedal pressure as the car slows down and brakes heat. The clearance allowed is usually from .010 inch to .015 inch. General recommendations for clearance are given in Fig. 5. The band and lining should conform to the brake drum. Fig. 6 illustrates common faults.

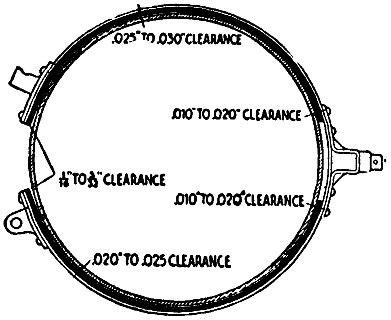


Fig. 5. Clearances between Brake Band and Drums Indicated Are Those Recommended When the Exact Specifications of the Manufacturer Are Not Known

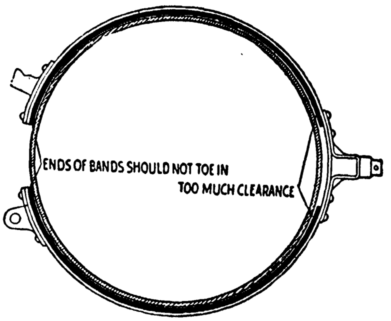


Fig 6. Too Much Clearance Should Not Be Allowed at the Points Near the Supporting Bracket at the Rear of the Brake Rigging

The ends of the bands should not toe in or the lining will wear rapidly.

Internal expanding brakes will free up as the drums heat, since they expand away from the lining and the pedal may need to be advanced instead of allowing it to give back. It is also true that if the pedal travel is just enough to hold the car when the drums are cold, it may not be sufficient to hold the car when the brake drums have heated and allowed the tension to come off the system. In other words, the pedal strikes the floor boards, but the drum has expanded beyond the limit of travel of the shoes and the brakes do not hold. Always have reserve pedal travel for internal shoe systems.

Equalizers and Rods. In the mechanical type of brakes, always check the position of the equalizer ends. They should be "squared across" the chassis. See that the rods are so adjusted that the levers and equalizer are right. Refer to Fig. 7.

Out-of-Round Brake Bands or Drums. Check up on the brake bands and drums for tight places. If the fault is in the band, have it rounded up. If it is in the drum, it will be necessary to remove the wheel and either replace or recondition the drum. Use a thickness gauge in this work to check clearance.

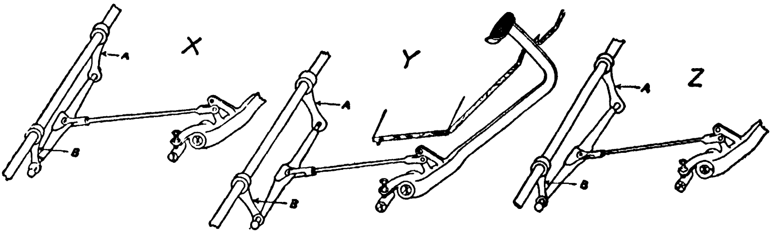


Fig. 7. *X*—Correct Position for an Equalizer When the Brakes Are in the "Off" Position
Y—Correct Position for the Equalizer When the Brakes Are Applied
Z—Faulty Action of the Equalizer Bar

Adjusting the Brakes. It is not possible here to tell how to adjust the various brakes. The main point is to see that internal shoes are set as close as possible without any drag and that the brake action is right. With external contracting bands, see that they are provided with the proper clearance at the drum; then see that the levers are of equal and proper angle and that the equalizer, if such is used, is square across; and finally see that the rods are properly adjusted with reference to pedal travel.

TROUBLE SHOOTING CHART FOR BRAKE SERVICE

Brakes Squeak

	Cause		Remedy
1	Exposed rivets	1.	Reset or replace rivets
2.	Loose or worn wheel bearing	2.	Tighten or replace
3.	Road grit or metal particles in lining	3.	Remove with wire brush
4.	Drum rust coating lining	4.	Remove with wire brush
5.	Frozen anchors, lever pins, and cams	5.	Free parts and lubricate
6.	Drums out of round	5.	Remachine
7.	Bands out of round	7.	True up
8.	Unequalized brake adjustment	8.	Readjust brakes
9.	Loose rear anchor stud	9.	Tighten or replace

TROUBLE SHOOTING—Continued

Brakes Chatter

Cause	Remedy
1. Lining loose on rivets	1. Reline
2. Drums out of round	2. Re-machine
3. Too much adjustment on pull rods	3. Release pull rods, adjust lining
4. Loose or worn wheel bearing	4. Tighten or replace
5. Loose axle spring seat	5. Tighten
6. Weak rear springs	6. Add extra leaves or heavier spring
7. Badly worn shoe or band supporter anchor pin	7. Replace worn parts

Brakes Grab

1. Equalizer frozen or off center	1. Free and secure proper equalization
2. Lining coated with grease	2. Reline
3. Sticky brake linings	3. Reline
4. Too much adjustment on pull rods	4. Release pull rods and adjust lining
5. Loose or worn wheel bearing	5. Tighten or replace

Brakes Drag

1. Broken or weak pull back springs	1. Replace
2. Frozen linkage units	2. Free and lubricate
3. Interference of linkage units or pedal	3. Clear parts
4. Release springs in improper position	4. Re-locate

Brakes Not Holding

1. Grease on lining from leaking wheel	1. Clean and replace felt in lining
2. Over-lubricated parts	2. Clean and do not over-lubricate
3. Rusty hand linkage and pull rod ends	3. Clean and lubricate
4. Road grit or metal parts in lining	4. Clean with wire brush
5. Too much adjustment on pull rods	5. Slacken pull rods, adjust lining
6. Drums scored or out of round	6. Re-machine
7. Exposed rivets contracting drum	7. Reset or replace rivets
8. Lever position incorrect	8. Release pull rods and adjust lining
9. Drum rust on lining	9. Remove with wire brush
10. Lining worn	10. Reline
11. Lining coated with grease	11. Reline

One Brake Will Not Hold

1. Lining coated with grease	1. Reline
2. Lining worn	2. Reline
3. Bent brake parts interfering	3. Straighten and line up correctly
4. Frozen pull rods and levers	4. Free and lubricate
5. Too much adjustment on one rod	5. Slacken off on rod
6. Weak release spring	6. Replace or tighten

Lining Wears Rapidly

1. Dragging brakes	1. Clean, free, and lubricate
2. Drums scored or out of round	2. Re-machine

Lining Glazed

1. Coated with rust	1. Remove with brush or reline
2. Coated with grease	2. Remove or reline
3. Coated with road dust or metal parts	3. Remove with wire brush

MOTOR VEHICLE BRAKE PERFORMANCE

Grading Table from an Initial Speed of 20 Miles per Hour

Comment	Stopping Distance
Commercially perfect for 4-wheel brakes	Between 15 ft. and 18 ft.
Excellent for 4-wheel brakes	Between 16 ft. and 18 ft.
Good for 4-wheel brakes	Between 18 ft. and 20 ft.
Fair for 4-wheel brakes	Between 20 ft. and 25 ft.
Poor for 4-wheel brakes	Between 25 ft. and 30 ft.
It's no longer a 4-wheel brake car	Over 30 ft.

Comment	Stopping Distance
Commercially perfect for 2-wheel brakes	Between 30 ft. and 32 ft.
Excellent for 2-wheel brakes	Between 32 ft. and 35 ft.
Good for 2-wheel brakes	Between 35 ft. and 40 ft.
Fair for 2-wheel brakes	Between 40 ft. and 45 ft.
Poor brakes, need attention	Between 45 ft. and 50 ft.
Vehicle unsafe on highways	Over 50 ft.

BRAKE-TESTING AND BRAKE-TESTING EQUIPMENT

Sometimes the men in the shop shy away from anything which savors of a "scientific treatment." As a matter of fact, most service men are scientists. They figure things in a "common sense" manner. They reason from cause to effect. They understand levers, hydraulics, vacuum, gearing, and a vast number of scientific terms. Friction is no new playfellow. It is used, considered, and taken advantage of daily by the scientific service men in every city and hamlet.

There is not a little science in the art of testing brakes on the street. But there is not enough science for the success of the garageman; certainly not the greatest possible success. Nor is it good business, viewed from the dollars and cents angle. Further, the street testing is not good psychology. By the way, this term psychology is another one which most garage men and service men understand little about, yet practice daily. Psychology is simply common sense when dealing with the "gray matter" of the customer.

Now it is hardly good common sense to make the same sort of test of a customer's car as he has made every time he has ever stopped it. He knows that the condition of the streets has too much to do with the test to make it "scientific." Too little of the braking results may be observed. It is good psychology to sell the customer on the fact that you have special equipment which will "prove" beyond all doubt the condition of each and every one of the four-wheel brakes, in relation to each other one. The fact that we have "gotten by" with the road test in the past is admitted. But the public is becoming "brake-test minded."

"Free air" is not a luxury for the customer, any more than it is a necessity to every garage and service station. Brake-testing equipment is shortly going to be just as great a necessity to the service station and garage man who wishes to hold and develop his business, as is the air compressing equipment.

This does not mean that every service station, large or small, general or special, is going to provide the same type of equipment regardless of cost and business prospects. Equipment suitable to the needs of the several demands is available. Without any attempt to indicate what type of equipment is to be preferred for any type of business, illustrations and short descriptions of some of the various types of testing equipment are here presented.

What Brake-Testing Equipment Should Show and Do. Brake-testing equipment should show that all brakes are equalized or balanced according to the design.

It should detect out-of-round drums.

It should duplicate road conditions in so far as possible.

It should show results in such fashion that the car owner is "sold" on needed repairs.

It should show the need of relining, adjusting, removal of grease, and other repair operations, if the brakes are in poor condition.

It should show the proper adjustment of properly serviced brake equipment.

It should save time for customer and shop.

It should improve the quality of work.

It should prove the balance between front-end and rear-end brakes, where a difference is specified.

It should save labor and misdirected effort.

It should develop confidence in ability to "whip" the toughest brake job.

It should enable the workman to detect leaking wheel cylinders and master cylinders in hydraulic brakes.

It should make possible the detection of the weak cross rod or shaft. The one which twists too much under pedal pressure.

It should eliminate the danger to car, passenger, and traffic generally of the side-skidding car, caused from unequalized brakes.

It should be so accurate that the workman can know the stopping characteristics of the car without a street or road test.

It should make it possible to eliminate causes of rapid brake deterioriation, such as is caused by bad drums, unequalized brakes, and improperly operating brake rigging

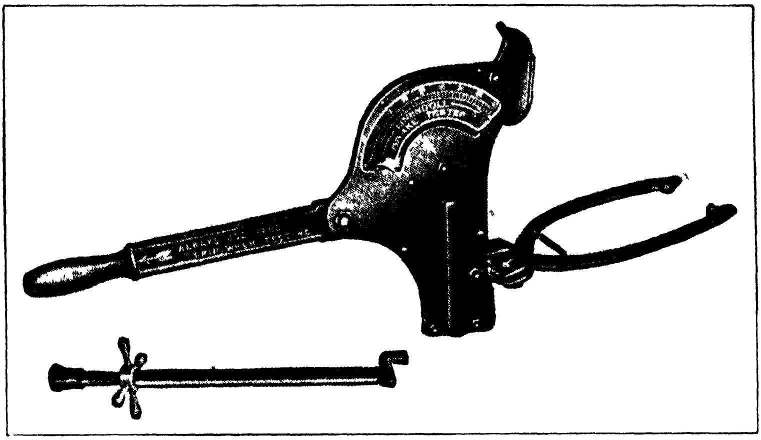


Fig 8 Linendoll Hand Tester

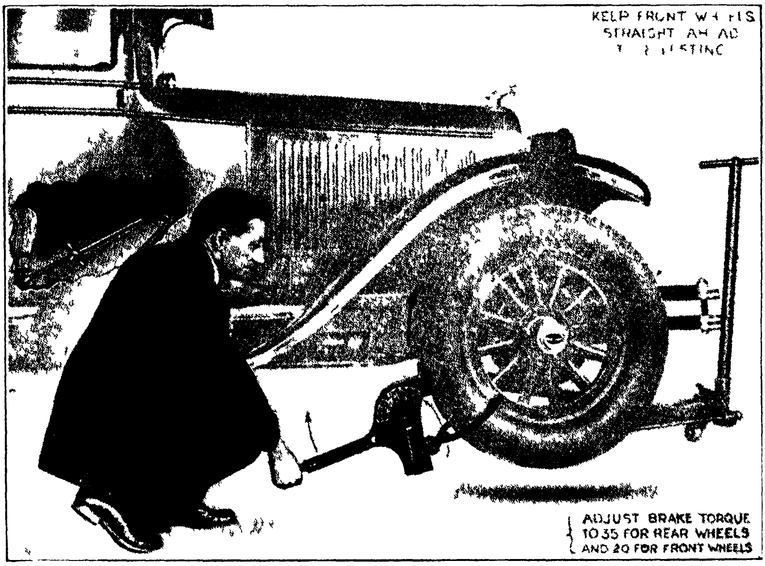


Fig 9 Using the Linendoll Tester

It should prove itself an economic necessity and a profit builder.

Types of Equipment. The simplest type of equipment is the lever, which is so designed as to test one wheel at a time and record the result on a graduated scale. Perhaps the most complex is the type which drives each of the four wheels at the same time and measures the result of the application of pedal pressure on gauges. Between these ranges of equipment are others, which vary in cost and ability to handle the job.

When using the Linendoll tester, Fig. 8, the first thing to do, after having all the brake rigging freed up, is to set the pedal jack in position. The next thing to do is to place the tester in position on one of the wheels, as shown in Fig. 9. It is better to have all the wheels raised at one time, since the test may then proceed from wheel to wheel and comparisons be made more readily. The dial gauge will indicate the pressure required to turn the wheel. The device has a ratchet attachment, so that the wheel may be turned throughout a full revolution to test the drum for eccentricity or out-of-round.

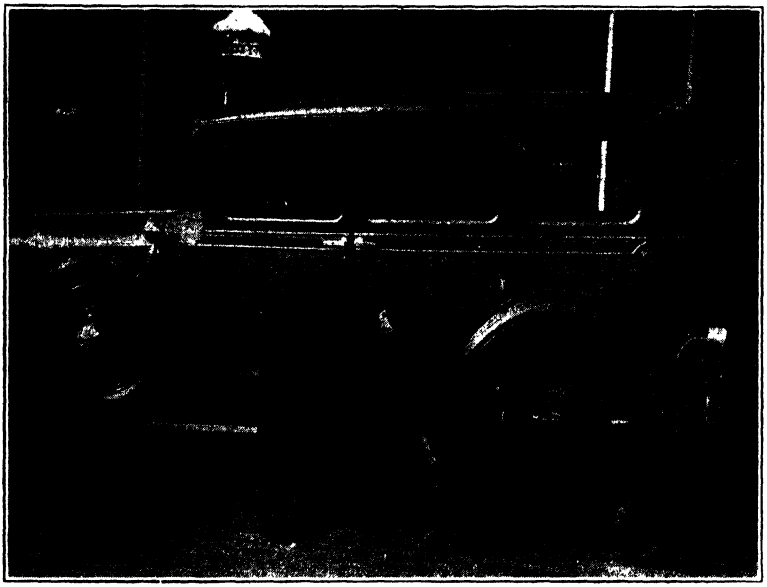


Fig. 10. The Patterson Equipment in Use

Another device, designed for testing one wheel at a time, is the Patterson brake tester, shown in Fig. 10. This is a portable device, which is readily brought to the car and takes up but little storage room when not in use. It is operated from the light socket and is moved quickly from wheel to wheel. The tester is rolled into position and then the lever thrown down so that the car is raised and at the same time the tester is anchored to the floor.

To make the test, the power is turned on, which causes the motor to rotate the drum on which the tire rests. As it is turned against the brakes, held set by the pedal jack, Fig. 11, the pressure developed within the hydraulic cylinder is registered on the dial. If all brakes show the same resistance, the same reading is secured. Front and rear wheels may be equalized and the front wheels balanced against the rear with the 40-60 ratio, as desired.

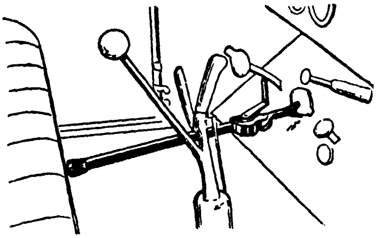


Fig. 11. A Brake Pedal Jack Is Used in Connection with Many Testing Devices for Equalizing Brakes

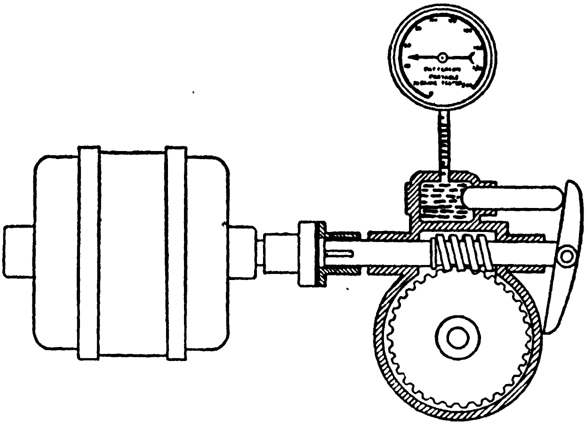


Fig. 12. The Principle of the Patterson Testing Equipment

The principle on which the tester works is illustrated in Fig. 12. Power from the motor is transmitted through the floating worm gear and the worm wheel, which is mounted on the same shaft as the ribbed cylinder on which the tire rides. The resistance set up by the brake causes the floating shaft to move endwise and register pressure on the fluid (through arm and plunger), which is recorded on the dial gauge.

The Jumbo tester is made in either two-wheel or four-wheel sizes. Fig. 13 shows the four-wheel unit. In most cases, the outfits are conveniently located on the service floor without the construction of a pit. The two-wheel unit has a rack or track arranged in connection with it so the car is on the level when testing. This track may be constructed to suit the local conditions. The four-wheel unit is so arranged that when the car is driven into position, the front wheels drop into position on the front testing rolls and then the entire front carriage of the tester moves ahead with the front end of the car resting on it until the rear wheels drop into position, thus the machine accommodates itself to all cars no matter what the wheelbase. When on the rack, the car is chained in position to prevent it running off of the machine and the front truck or carriage of the tester is locked to the track.

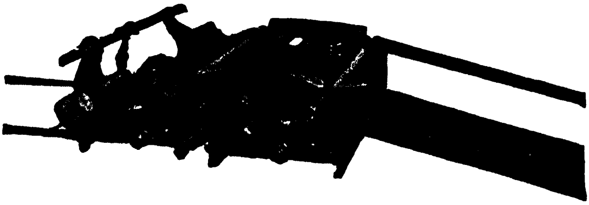


Fig. 13. Jumbo Equipment

When making tests with the Jumbo tester, the pedal pressure normally used to stop the cars from 30 to 50 miles per hour is used. As shown in Fig. 14, the device is so designed that when braking pressures are applied, the roller assemblies rock forward. This results in the hydraulic pressure plunger being forced into the hydraulic cylinder and then registering the force of this forward movement on the oil within the cylinder. The amount of pressure in any cylinder of the four is registered on the gauges, two of which are at the front of the machine and two at the rear.

It is possible to balance brakes on this machine to a nicety. For instance, comparative readings on the gauges of 500 to 600 would be good equalization for the front-wheel brakes of an average car, such as the Buick; and 700 to 800 on the rear wheels would not only equalize them satisfactorily with reference to each other, but would balance them properly with the front wheels.

Another four-wheel testing outfit is the Cowdrey aynamic brake tester. This is also motor driven. The general design of the equipment, which is available in a variety of forms, for either two-wheel or four-wheel installation, is shown in Fig. 15. The tire of the car rests on the driving rolls *A* and *B*. The wheel is turned against the resistance of the brake as these rolls are driven by the electric motor *C* through the worm and gear *E* and the planetary action *F*. The weighing or recording mechanism is shown at *D*. The "pull of the road" is indicated on an accurate weighing scale. The reading is

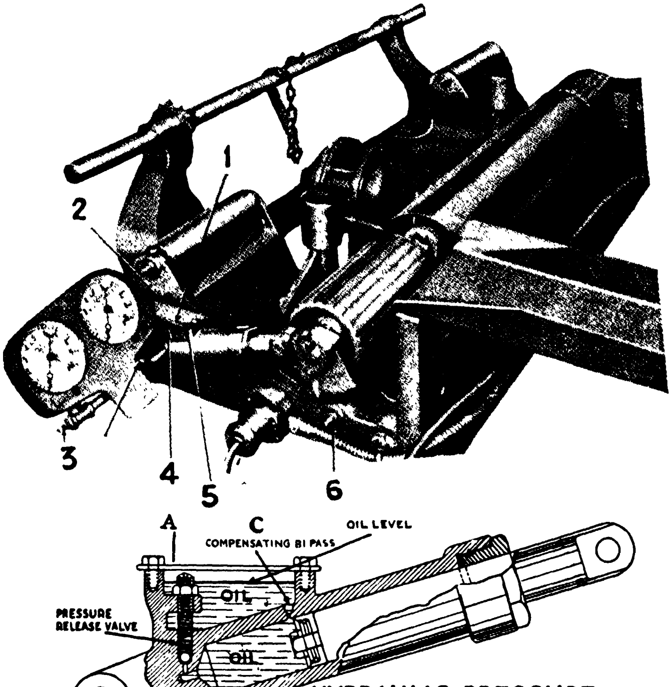


Fig. 14. The Principle of the Jumbo Testing Equipment
1—Pressure Release Valves. 2—Reservoir Oil Cap. 3—Covered Fittings. 4—Oil Reservoir. 5—Compensating By-Pass. 6—Whole Roller Assembly Rocks Forward on This Shaft.

obtained by means of the planetary action of the train of gears. The amount of this action is directly proportional to the brake action.

One recording gauge is provided for each wheel. A pedal jack is used to hold the pressure evenly on the brakes and the equalization

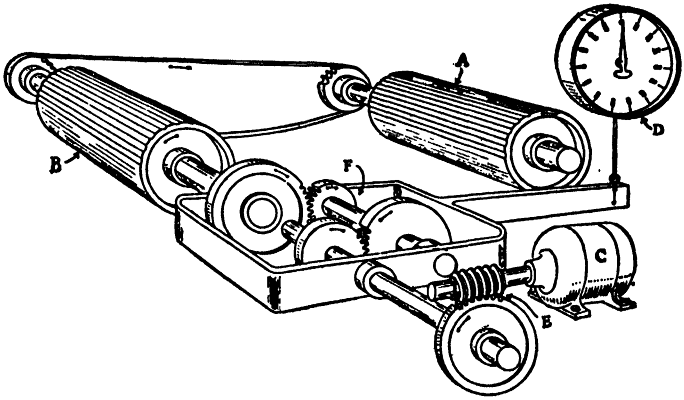


Fig. 15. The Principle of the Cowdrey Testing Equipment

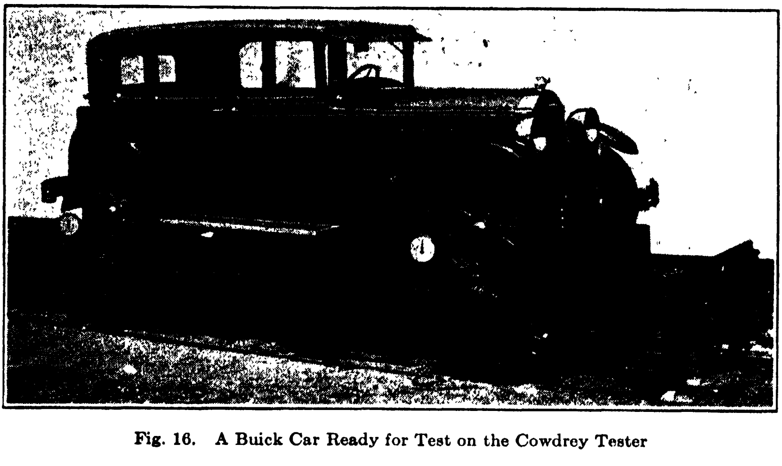


Fig. 16. A Buick Car Ready for Test on the Cowdrey Tester

and balance can be read quickly. By adjusting the brakes, exact equalization between wheels is possible and balance between front and rear. During the testing operation, the car is held from climbing the rolls by means of a chain.

The Cowdrey equipment is made in a great variety of sizes and capacities. Certain units, Fig. 16, are designed especially for the small service station, others for the large passenger-car service station, others for the truck and bus maintenance station, and still others for the factories; the latter usually being pit installations.

The Rite-Way brake tester, Fig. 17, employs the hydraulic principle in registering brake resistance and is adjusted automatically for any size tire, providing an unlimited range for the shop using this portable tester. High and low spots in the brake circumference are easily detected and the hydraulic pump and gauge record the pressure accurately. It is easily operated.

After seeing that all bands have the proper clearance, the pedal depressor is adjusted to hold the pedal about 2¼ inches above the floor board. The tester is hung on one of the rear wheels, over the tire, and the hooks are drawn up until they are tight on the tire and locked. The hydraulic pump is placed on the pin extending from the lower front corner of the cradle and the test is made with the travel of the car. It is a simple process to equalize the resistance of opposite wheels and establish the proper ratio between the front and rear wheels. This device is a reliable detector of inefficient linings, for the hydraulic pump and gauge will not give a false reading.

Fig. 17. The Rite-Way Hydraulic Operating Brake Tester

The Raybestos brake tester, Fig. 18, works on a principle which in itself is rather simple. A car is run onto the machine and then fastened in position so that it may not move forward or backward. Compressed air is used as a source of power to pull the movable sections under the wheels. These sections are arranged in pairs and hooked to the cylinders by equalizer rods and piston rods.

In use, the force of the air actually pulls the sections backward under the road wheels of the car in much the same manner as the car passes forward over the street in the ordinary forward application of the brakes. It will be seen that since the four movable sections are equalized, the wheels on which the brake holds least will start moving first. As the wheels start moving, the fact is indicated by a light for that section, which registers on the instrument board and is close to the car pedal location on the left side of the car and test outfit. As the action proceeds, other sections start moving and these in turn are registered on the lights. The filament in the lamp begins to glow and gradually grows brighter as the platform moves backward until it reaches full intensity at the end of the travel of the platform.

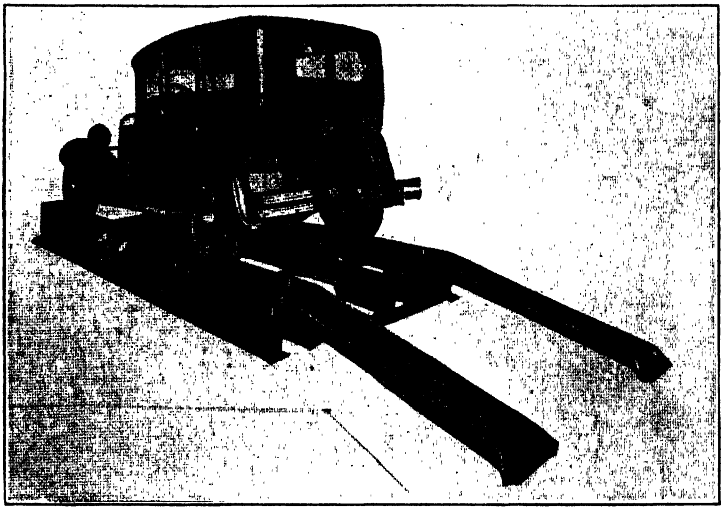


Fig. 18. Ready for Brake Test on the Raybestos Tester

At the left of the instrument board is a gauge. As the lamps are illuminated, the operator watches the gauge. The indicating hand shows the brake resistance in pounds. This makes possible a double check. As the air is gradually admitted to the cylinder, the indicating hand of the gauge will advance until it reaches a maximum point on the dial, then it will fall back slightly. As the next platform begins to move backward, the indicating hand will again advance to a still higher position. This process will continue as all four platforms move to the rear.

When the resistance of each brake has been ascertained, the air pressure is shut off. If the valve is turned slightly further than the shut-off position, the air pressure is released. To equalize the brakes, take up on the brake that is weak or release the brake that is strong, depending upon the position of the pedal. The platform may now be returned to normal position by turning the right-hand valve.

The Weaver four-wheel brake tester, Fig. 19, works to register the relative braking efficiency of the four-wheel brakes when the car is driven over it at a medium speed and then just as the front wheels pass onto the front platform, the driver sets the brakes. Four columns of liquid are used to register the relative braking effect. These may be noted within the glass cylinder on the brake-machine pedestal. This particular machine is designed to be placed in a driveway into a garage or service station so that the driver of the car as he enters may test the brakes. The results of the test are read direct from the driver's seat or by the service man on the outside.

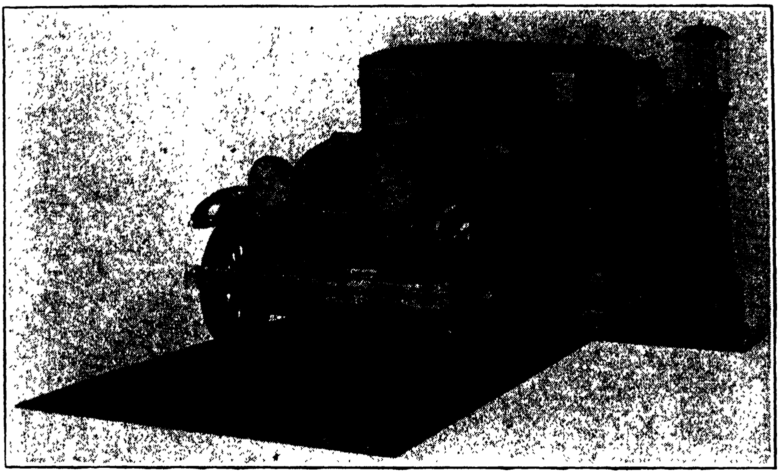


Fig. 19. Weaver Automatic Four-Wheel Brake Tester

As long as the car is on the machine, the brake reading remains visible. When the car is driven from the tester, the liquid in the tubes returns to the level so that another machine coming in may use the device at once. The machine is designed as a silent salesman of brake adjustments and relining work.

CHECKING INTERNAL BRAKE DRUMS FOR CONDITIONS AND INTERNAL BRAKE SHOES FOR FIT

The fact that it is practically impossible to know the exact condition of the brake drum and the brake-drum shoe fit when internal brakes are assembled makes some form of special device which will show the condition of these parts a practical necessity for the best results. The Wadell brake and drum gauge shown in Fig. 20 is designed to care for all makes of cars. It is used as follows:

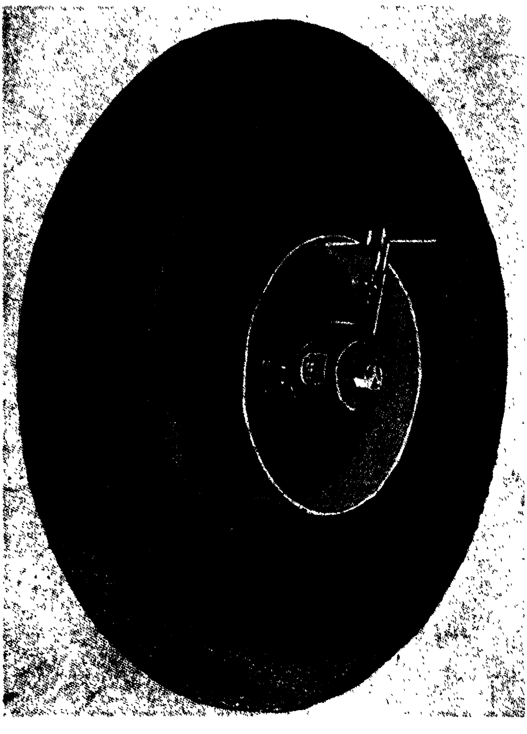


Fig. 20. Set the Inner Finger to the Drum and Gauge It for Accuracy

Select the proper bushings and arbor for the job at hand. Mount the arbor in the wheel hub and adjust the gauge finger to the internal surface of the drum. Rotate the gauge while seeking the high point of the drum. If the drum is out-of-round or warped, the fact will show as well as the amount. If the drum shows scored, badly worn, warped or out-of-round, the job should be reconditioned on the brake-drum lathe. When the drum is in condition, set the gauge finger to it again. Remove the gauge and apply to the axle. Revolve it about the shoes and brake lining to check adjustment.

Adjust the shoes to bring the lining into contact with the inner finger of the gauge. This finger is set so as to provide proper clearance for the shoes when the outer finger is properly set to the internal surface on the drum, Fig. 21. In other words, the two fingers, as sent out by the factory, are designed to work together.

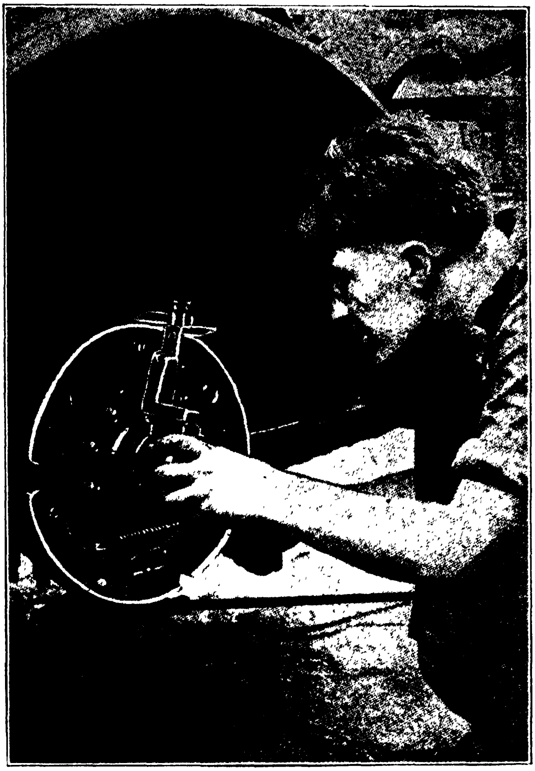


Fig. 21. Set the Brake Shoes to the Outer Finger and Proper Clearance Is Assured

BRAKE RELINING

One of the most profitable of services in the automotive field is that of the brake service station. It is also a branch of the service requiring a fund of information and ability to diagnose trouble.

The external brake band usually carries a woven lining. This is comparatively easy to install. Most of the brake-lining business over a long period of years was built up on the installation of the woven lining on the internal expanding shoe and the external contracting band. On the two-wheel brakes almost any type of lining could be used and made to equalize and give service. At no other point of the brake servicing field has there been a greater change than in this one particular item.

Owing to the fact that many of the brakes are now operating upon the servo principles, the type of lining selected must be in accord with the design of the brake system. In many cases this means a moulded instead of a woven lining. The point to be held in mind here is the fact that not all brake linings have the same friction qualities. Since the brake drum tends to drag the servo shoes around with it, it will be seen that the friction coefficient of the lining will have a great deal to do with how effectively the primary or servo shoe is carried around. If a lining of improper friction qualities is applied, one of two things will result—either the servo action will be weak and the customer will complain about too much effort being required to set the brakes, or a severe action will be exerted which may result in the wheels of the car being locked and thus causing an accident. The existence of these rather essential conditions makes it necessary, when servicing a system of brakes of the servo principle, to take the old brake shoes off the car and return them to the brake service station maintained by the manufacturer of the brakes. They will be exchanged for shoes which have been relined and burnished and ready for installation.

On the other hand there are many jobs of brake servicing on which the job of relining may have to be done in the service station. These can be handled at a profit, depending on the type of equipment which is available. If but a few jobs are handled a month, it is not a good policy to invest in brake-lining machinery. The work can be done by hand in a very satisfactory manner. However, if a considerable quantity of brake servicing work is done, a relining machine will pay for itself.

Relining Brakes by Hand. After the car has been placed on the jacks, all of the bands and shoes, Fig. 22, should be pulled from it and should be cleaned, Fig. 23, preparatory to doing the relining work.

Use a chisel to knock off the old linings. Next proceed to measure up the bands to learn the amount of material required. When the lining is at hand, the usual method is to lay the lining around the inside of the band and mark it for length, or use a steel tape or a piece of soft wire, as shown in Fig. 24. Since considerable of the profit in the brake relining job is to be made from the sale of the lining, many shops prefer to buy standard sizes of lining in 50-foot rolls, from which they cut the lining required, Fig. 25.

Applying the Lining. Drill the lining and rivet one end to one end of the brake band. When drilling, use a countersink and drill combination. In Fig. 26 two methods for applying the lining to the band are shown. In the case of the improper method, the rivet head is not countersunk a proper depth. This results in a squeaking brake as the head of the rivet is in contact with the steel of the drum. In the proper method of counterboring, the head of the rivet is countersunk approximately one-half the thickness of the lining. Use care to see that the counterbore does not extend more than half-way through the lining. Otherwise the lining may be drawn away from the band or shoes when the brakes are applied.

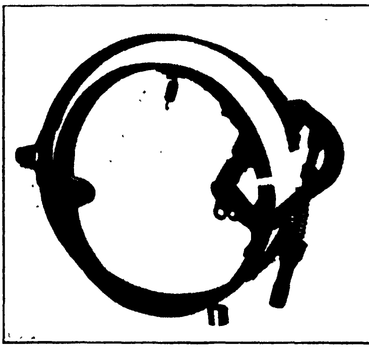


Fig. 22. A Brake Band and Shoe as They Ordinarily Appear When Removed for Relining

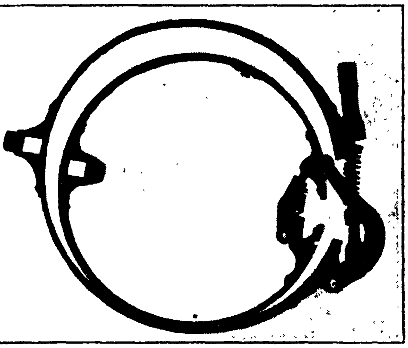


Fig. 23. The Same Brake Band and Shoe Cleaned, Ready for Relining

Having one end of the lining riveted to the band, the other end of the lining is fastened to the other end of the band, as shown in Fig. 27, allowing a buckle to show in the lining. Drill and rivet the second end of the band. Next grasp the lining, as shown in Fig. 28, and force the buckled portion in against the band. This will cause the lining to lay in perfect contact with the band all the way

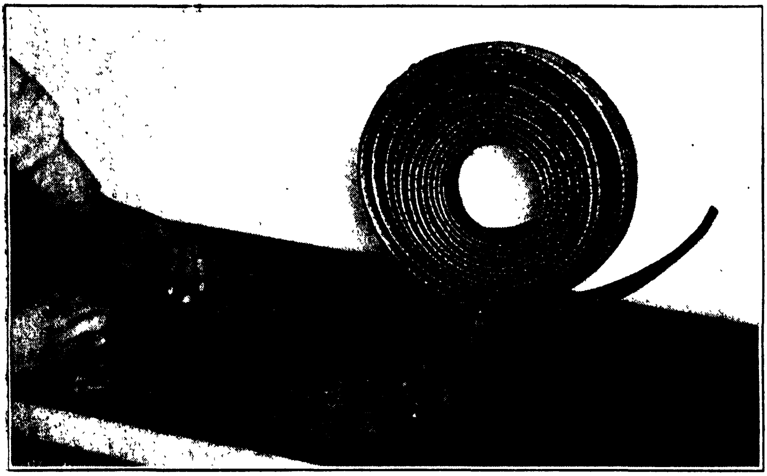


Fig. 24. The Amount of Brake Lining May Be Measured with a Steel Tape or a Soft Iron Wire

If the lining is at hand, it may be slipped in position and the length measured directly on it.

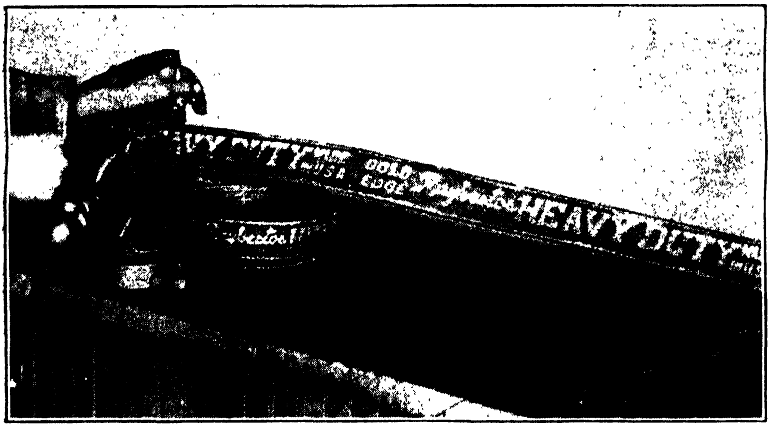


Fig. 25. Brake Lining Is Usually Cut with a Hand Hack Saw

around. Enough lining should be provided so that it can be hammered into form, as shown in Fig. 29. If this method is not used, it is very likely that the lining will not lie in perfect contact with the band, and, as a result, "flat places" occur, making it impossible to secure a proper brake adjustment when the linings are installed as these "flat places" are springy. After the lining has been hammered, the drill may be run through from the outside of the band and the countersink used from the inside, and the lining counterbored, after which the rivets may be set.

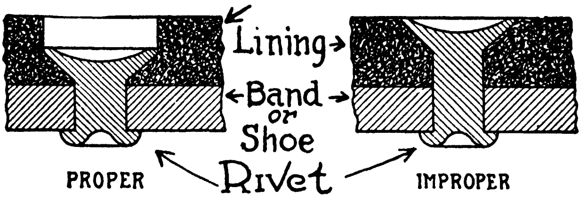


Fig. 26. The Proper and Improper Method of Drilling and Setting Brake Rivets

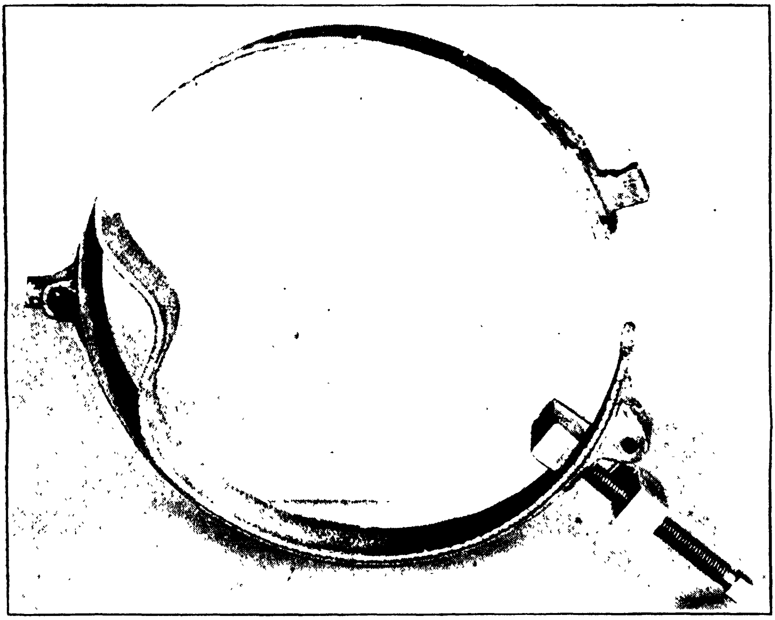


Fig. 27. When Applying the Lining, Rivet One End and Clamp the Other End, Allowing a Buckle in the Middle

Setting Rivets. When setting rivets by hand, the rivet is selected with considerable care so that it will be of proper length and diameter. Place the rivets through the lining and then use a square end punch or a piece of rounded steel with a cross section just as large as the rivet head. Hold this steel in the vise in such a manner that the work may be swung over the vise and the rivet head brought to rest on the end of the steel. Drive the band down around the rivet so as to force the rivet up through and in close contact with the lining, after which a few sharp blows with a hammer will properly set it. When riveting lining to the band or shoes by the hand method, solid rivets are used. These may be of brass, copper, or aluminum. Some manufacturers claim that the brass rivets are superior, because they are not so likely to cause squeaking of brakes when the heads gradually come in contact with the brakes after considerable wear has occurred.

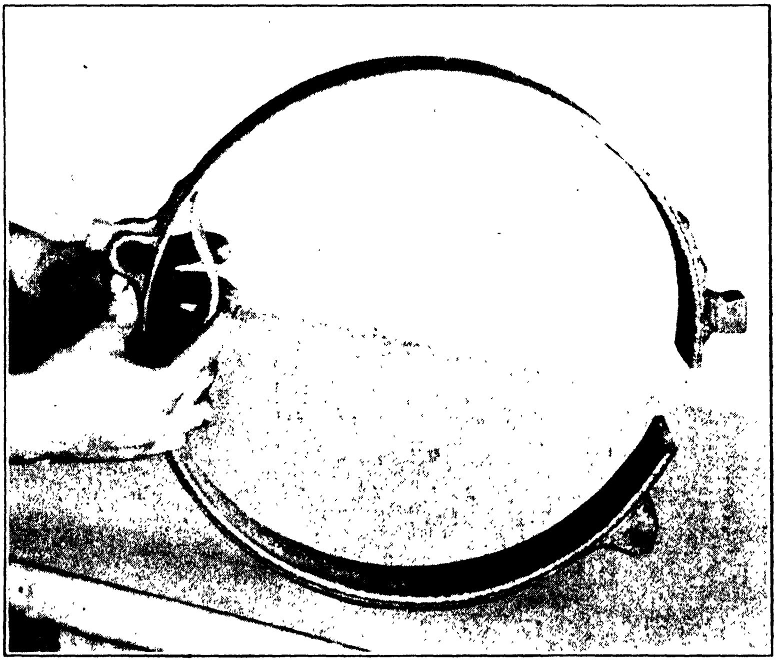


Fig. 28. Pulling Out the Buckle

Relining Brakes With a Power Machine. For the sake of "speeding up" brake relining and making the job of brake relining a profitable service operation, a number of special brake relining machines have been designed and placed on the market. Primarily, these machines consist of one unit for drilling and countersinking and another unit for setting the rivets. Some machines are provided with additional features, such as a device for cutting rivets when removing old lining. Fig. 30 shows a mechanic using a machine of this nature for a rivet chiseling operation. The brake band is held in position on the anvil, with the chisel *A* in the head of the machine. As the foot pedal is forced downward, a considerable pressure is exerted on the chisel so that the brake-lining rivet burr is cut away.

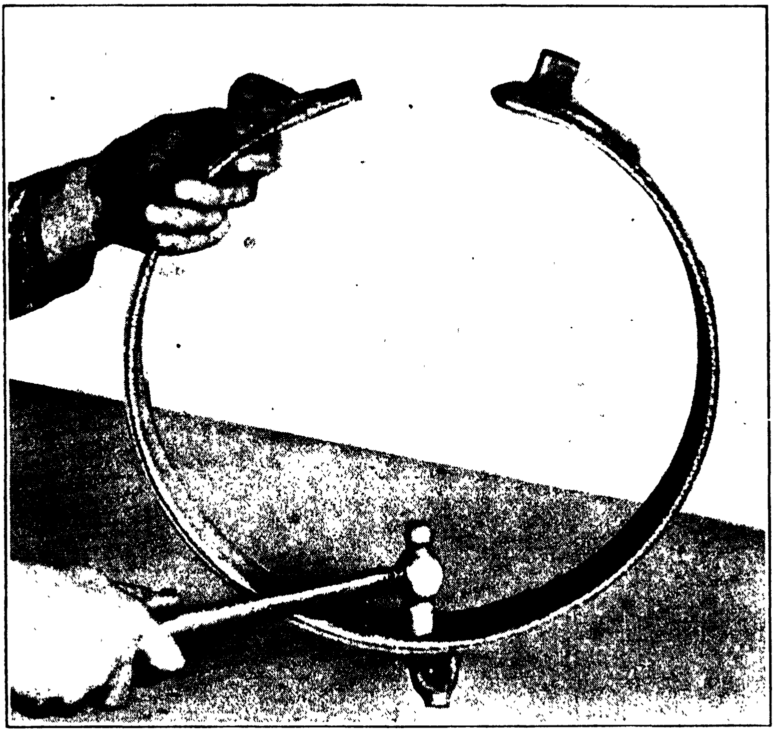


Fig. 29. Hammering the Lining to Make It Conform to the Band

When preparing a brake band for relining, the process is the same regardless of whether or not it is to be done by hand or by a brake relining machine. In Fig. 31 the lining is being drilled from the outside of the band preparatory to fastening one end. First the foot pedal is forced downward and the band is located under the drill point *A*. The weight of the machine causes the drill to force its way through the lining. Holding the band and lining assembly in position, the foot pedal is forced down until the countersink *B* comes up and countersinks the lining at the point just drilled. The amount of countersink is controlled by a stop on the machine so that, once set, the complete set of linings must be counterbored in a uniform fashion.

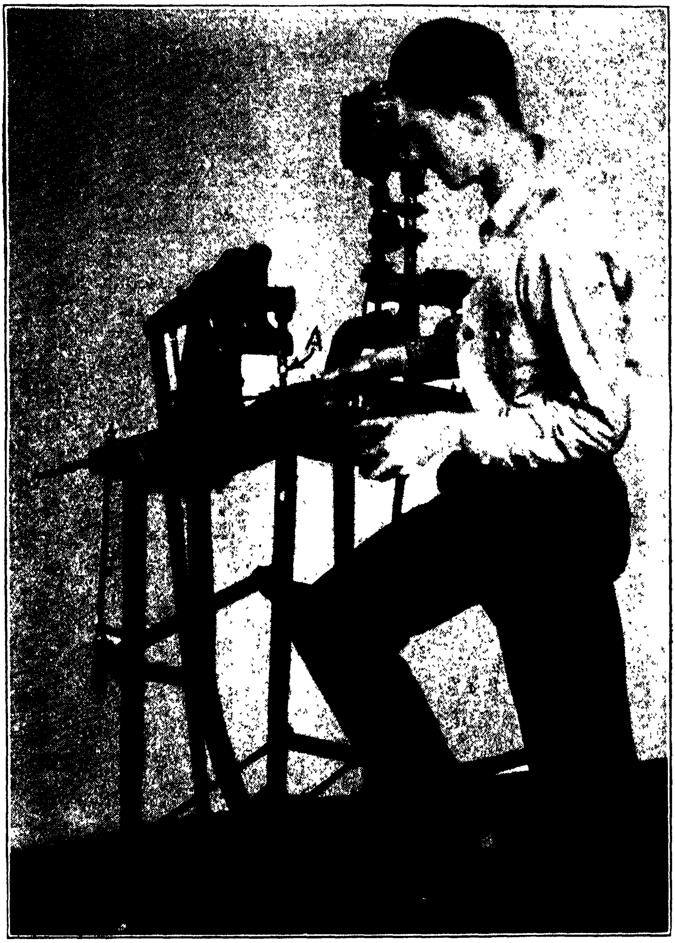


Fig. 30. Using a Brake-Lining Machine to Cut Off Rivet Burrs

After the holes are drilled and counterbored for the rivets, the rivet attachment is used for setting the rivets, as shown in Fig. 32.

This is the same attachment as that which was used for chiseling off the rivet burr, but when doing riveting, other tools are installed. The anvil *A* is placed in position on which rests the rivet head and a rivet set *B* is placed in the head of the machine, which will form up a burr on the hollow type rivets which are used with machines of this kind. The completed job is shown in Fig. 33.

A great variety of machines designed to do this work are on the market. Sometimes the several units are built on one base, and in other cases they are built up separately for mounting about the shop in convenient locations.

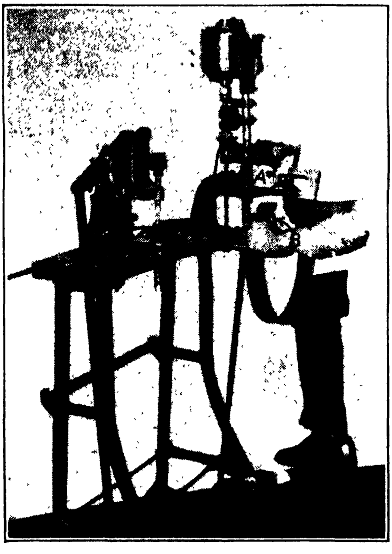


Fig. 31. Drilling and Countersinking the Brake Lining on a Brake-Lining Machine

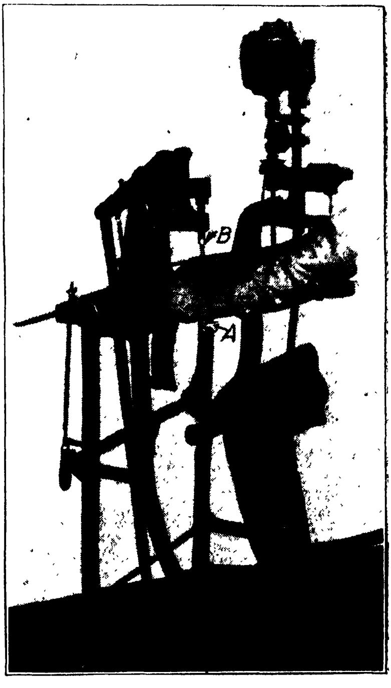


Fig. 32. Setting the Rivets on a Brake-Lining Machine

Riveting Linings to Brake Shoes. The brake shoes are of a variety of forms, and earlier cars carried a shoe which was more or less flexible. In most of the internal-expansion four-wheel brake jobs, the shoes are die castings of aluminum or aluminum alloy, so that they are interchangeable one with another of like design.

When it is necessary to reline them in the local shop, all of the shoes should be relined with the same grade of lining, and this should be selected as near as possible according to the car or brake manufacturer's specifications. Applying this lining to the shoes is more difficult than applying the lining to the external band. The linings are usually applied in either two or three sections. These short sections are a little more difficult to handle and have them lie close to the shoes when the job is complete. In many instances it is necessary to have the linings applied by hand, since the nature of the shoe

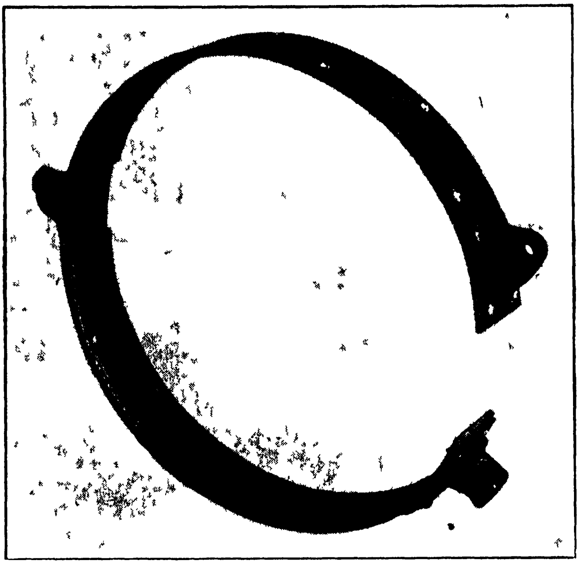


Fig 33 A Neat Job of Brake-Band Relining

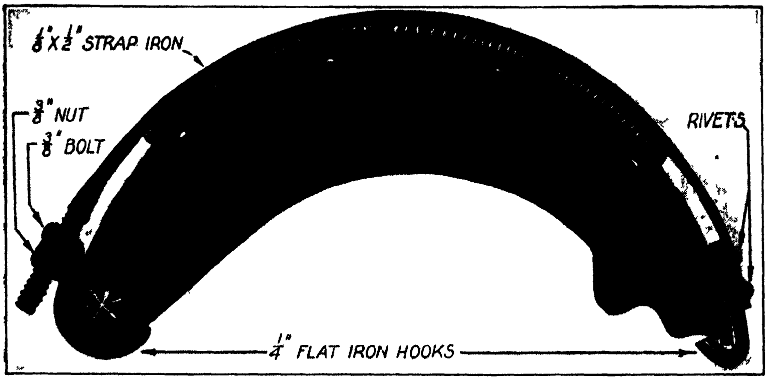


Fig 34 A Clamping Device for Holding the Brake Lining to the Shoe While Riveting

casting makes it very difficult to design a machine which will do universal work when relining shoes.

When relining internal brake shoes, the chief consideration is to see that the lining conforms to the shoes and that there are no bumps. It is useless to attempt to adjust a set of brakes if the shoes are not properly lined. The bump will give a dragging action to the brake, causing heating and other trouble. The amount of clearance allowed between the internal shoes and brake drum is so slight that trouble is certain to arise from an irregular lining job. The clamping device shown in Fig. 34, which may be made in the shop, will draw the lining tight and hold it while rivets are being set. The ½-inch strap iron is not in the way of setting the rivets and the device is left in position until all rivets are set.

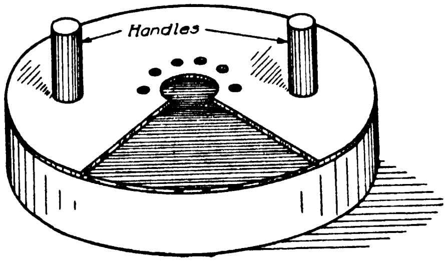


Fig. 35. Dummy Brake Drum for Adjustment Work

Dummy Brake Drum Useful. Where a great deal of brake work is to be done, particularly in a shop where the greater part of the cars are of one make and the brakes all of one size, a great deal of time and trouble can be saved by having a set of test drums. An ordinary brake drum with a section cut out so that the action inside may be observed is all that is necessary, except that it should be mounted suitably. As shown in Fig. 35, it is well to fit a pair of handles to the brake drum to assist in turning the drum when the adjustment is being made. The real saving consists of the work which is saved in putting on and taking off the heavy and bulky wheel each time when the adjustment is changed. The test drum is put on instead, and it is easily and quickly lifted on and off. Adjusting rings are made up as skeleton drums and have spokes which support a hub that fits the spindle or axle end and thus assures the shoes being concentric with the wheel bearings. This is special equipment and may be secured through the jobbers or factories.

PREVENTING BRAKE SQUEAKS

A great many problems are involved in the prevention of brake squeaks, and engineers have spent considerable sums in trying to solve these problems. In Fig. 36 the workman is cutting away a short section of the lining at the rear of the band. This has the effect of allowing some of the dirt to escape, since the sand and gravel picked up along the highway may become embedded in the brake lining and cause squeaks.

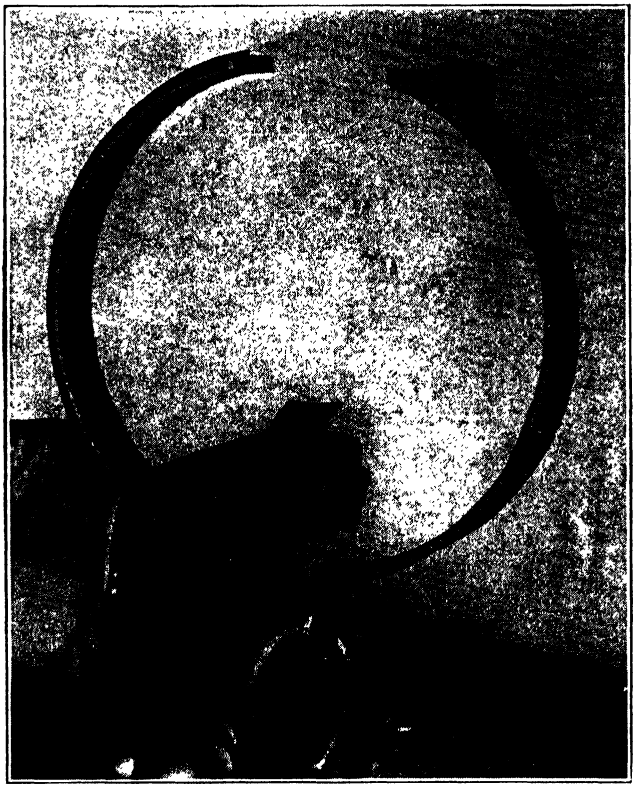


Fig. 36. Using a Hack Saw to Cut Out a Section of the Lining to Prevent Squeaking

Some brake manufacturers at times have recommended that the cut be made on a bevel rather than square across, and this, too, has been found acceptable by many garage men. A further application of this principle, sometimes made by garage men in severe cases of squeaking brakes, is making bevel or spiral cuts in the lining at points about 6 inches apart. When making these cuts, it will very likely be found necessary to install additional rivets, which will mean drilling the band for them.

A similar application of this principle is sometimes used without cutting all the way through the lining. The brake band or the brake shoe is taken to the emery wheel and the corner of the emery wheel is used to grind spiral grooves in the brake surface. These grooves may be 2 to 3 inches apart and should be approximately $\frac{1}{16}$ inch in depth.

Another method used to rid a set of brakes of undesirable noise is removing all the internal brake shoes and roughing up the internal surface of the brake-shoe lining. This may be done by means of a stiff wire brush, an old file, a wire brush buffer, or by grinding the surface very lightly.

A cause of noisy brakes is glaze, which frequently forms on the brake-lining surface. The brake drum surface may be highly polished. These two very hard surfaces do not prevent a proper friction-producing combination, except in severe pedal pressure, at which time noise or chatter may arise.

It has been found that if a fine cut file is used to scratch minute hair lines across the highly polished internal surface of the brake drum, these scratches act as teeth to cut off the glaze on the brake lining and to keep it from glazing further, so that the desirable "soft pedal" action with brakes free from noise is more readily secured.

RECONDITIONING BRAKE DRUMS

Before the advent of the four-wheel brake systems and their general complication of assemblies, little thought was given to brake equalization other than having a car which could be stopped without its leaving the road. When the public accepted the four-wheel brakes and the high car speed idea, they also accepted the proposition that four-wheel brakes were efficient, safe, and noiseless.

While in the old two-wheel brake systems an out-of-round or scored brake drum was considered something to be put up with, this situation does not exist with reference to four-wheel brakes. Customers expect and demand those things they have been sold by the new car dealer and factories through the advertising pages. A mechanic or brake service-station owner must recognize these facts and set up his shop with equipment which will give the type of service that car owners expect. The grade of lining and its method of application have much to do with the service the job will give. Not all of the fault is with linings; a part of it may well be laid to the drums. Drums which are out-of-round, set on the wheel off center, scored, as shown in Fig. 37, or those drums having hard and soft spots are certain to develop troublesome conditions.

Many car manufacturers machine the brake drums after they have been mounted on the wheel, so that the brake drum does offer not only a true surface but also a true turning surface to the action of the brake-shoe lining. On the other hand, production demands for low cost forces thousands of cars upon the road each year which are supplied with drums stamped from sheet metal and bolted in position on the hub without further machining or truing operations. While the high standard developed and held to with reference to stamping machinery gives a drum that is fairly accurate, it often happens that by the time it is mounted on the wheel slight irregularities creep in, and the job develops high and low spots, as is evidenced by the high and low points when an attempt is made to set up the drum in service.

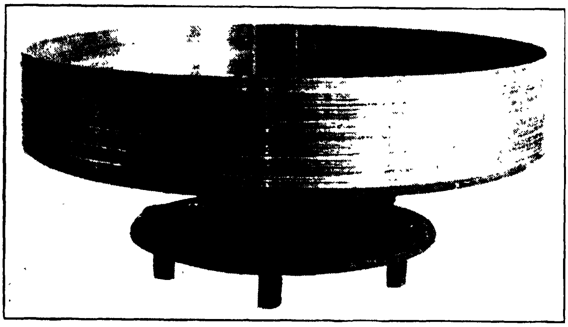


Fig. 37. Brake Drum Scored on Both the Internal and External Braking Surface

When a job of this type comes into the shop and the car owner is expecting the utmost in point of efficiency and quietness, then it is up to the shop to recondition the drums in order that proper service may be given by the job. Drums which are badly scored, as the one illustrated in Fig. 37, should be reconditioned by turning or grinding. When old drums are replaced, the new ones should be bolted to the wheel and then the wheel assembly mounted on arbors which correspond to its normal mounting position, so that the drums may be turned concentric with the wheel bearing when the job is finished.

A prime requisite when reconditioning brake drums is to have a brake-drum machine which will permit the wheel and drum to be swung as a unit. There are a number of these machines on the market especially designed to handle a wheel, even with the tire mounted. The question arises as to which gives a better job, a turned drum or one which has been ground. Some engineers contend that a "too smooth" surface is likely to set up squeaks or chattering and claim that a turned drum, having some lathe tool marks on it, will serve to break down the hard surface which sometimes forms on brake lining and keeps the lining in condition to give the much desired "soft pedal" action.

There are splendid machines on the market which will either grind or turn a brake drum and in some instances the same machine will do either. Of one thing there can be no question, and that is the need of grinding or turning to recondition a drum when it is badly scored or out-of-round, and the practice of reconditioning drums is universal throughout the country.

A prime consideration is to have a machine which will swing the wheel and drum assembly, as it is useless to recondition a drum when it is not bolted in position as it would be certain to be out-of-true when it was mounted on the wheel and the wheel mounted on the car.

BRAKE-DRUM LATHES

Bendix Brake-Drum Lathe. When truing the brake drum on the Bendix lathe, Fig. 38, the wheel assembly is first mounted on a special arbor which is equipped with adapters fitting snugly into the hub bearing races. The arbor and wheels with tires are then mounted between the vertical centers of the lathe, having the weight of the job resting on the headstock center. The wheel is turned by means of a lathe dog which is attached to the headstock face plate, the dog engaging between the spokes of the wheel or in the holes usually found in disc wheels. After the tailstock center has been properly adjusted, it is tested for running.

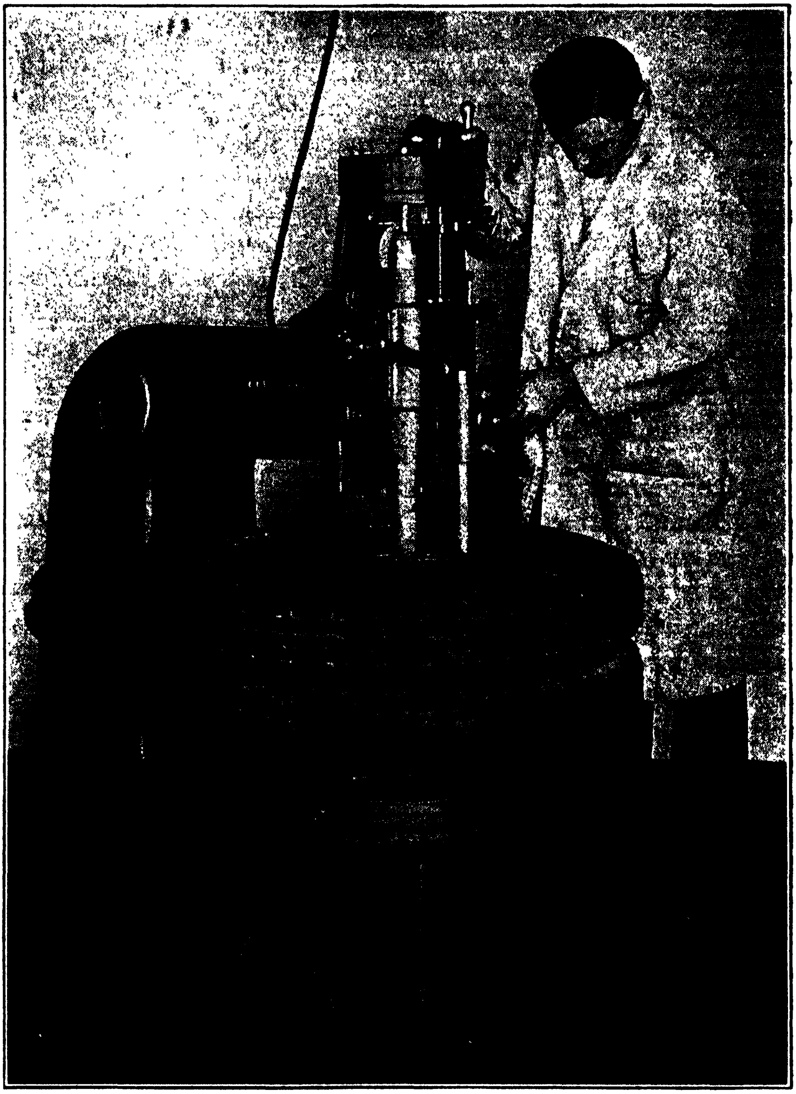


Fig. 38. Bendix Brake-Drum Lathe

The next step is to set up the cutting tool and test it against the drum to find out the approximate amount of material to be removed. Usually not more than two cuts are required, and only that amount of material is removed which is necessary to true up the out-of-round and scored drum. The machine is driven by means of an electric motor which is fully enclosed. The tool feed is controlled by means of a lead screw within the tailstock, just above the cutting tool. The cutting tool advancement is controlled by means of a screw. This machine may be equipped with a grinding head or attachment.

Reis Brake-Drum Machine. This machine, Fig. 39, is a combination brake-drum grinder and lathe. The arbors, wrenches, and face plates are shown lying at the base of the machine. When using the machine as a lathe, the grinder head is swung to the side and a tool post is inserted. When using for a grinder, the tool post is removed and the grinder head swung into position. The infeed of this machine is graduated in thousandths of an inch, so that the depth of cuts may be known. The crossfeed is automatic, and the machine may be set up so that it will automatically reverse as may be necessary in the grinding operation.

Tru-Drum Lathe. The Tru-Drum lathe, Fig. 40, is one of the oldest machines designed for this particular work. The wheel and drum assembly is swung into position on a headstock carrying spindles to which the wheel is attached by means of adapters, so that any style of wheel hub may be fitted. The usual infeed and crossfeeds are supplied. When set up, the feeds are automatic.

South Bend Brake-Drum Lathe. This machine is designed along the lines of the standard screw-cutting lathe. The main difference is the height of the headstock and the tailstock from the bed of the lathe, this distance being secured by the special design. Fig. 41 shows a 36-inch lathe with a passenger-car wheel and tire mounted between centers on a special self-centered mandrel, Fig. 42. The outer universal adapter *C* and the inner universal adapter *D* are automatically centered and align the wheel on the arbor when these adapters are forced together by the screw action of the arbor nut. After mounting the wheel and arbor assembly in the lathe, the job is driven by means of a special dog or face-plate driving tool.

Turning the Drum. The actual work of refacing or turning a drum is quite similar to any other lathe work. Speeds must be care-

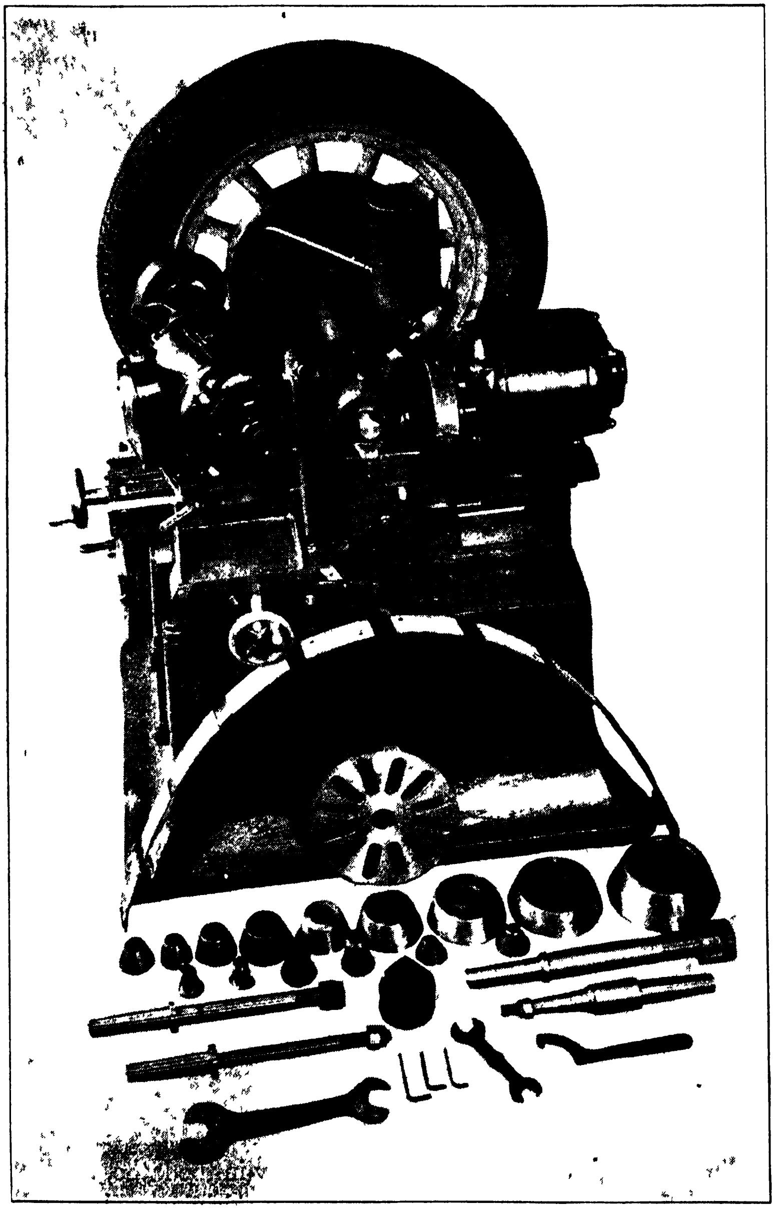


Fig 39 Reis Brake-Drum Lathe and Grinder with Attachments

fully figured so as to prevent the burning of the tool. If the tool is burned or wears rapidly, the quality of the work will suffer. High-grade tool steels are available and are usually used in the Armstrong type holder, Fig. 43, which illustrates the method of refinishing an internal brake drum by the turning process.

Perhaps the greatest difficulty encountered in turning brake drums, aside from having tool bits not properly sharpened and maintained, is the tendency of the brake drum to chatter when the turning is under way. The usual method used to overcome this chatter is to attach a coil spring around the outer surface of the drum when turning the internal surface of the drum, Fig. 43. When truing an external surface, a special flat spring is sprung into the drum where it exerts the outward pressure, Fig. 44.

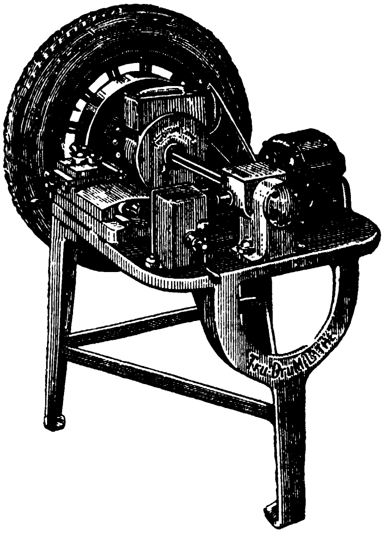


Fig. 40. Tru-Drum-Brake Lathe with Wheel Assembly for Truing

Some brake manufacturers recommend the use of rings to fit inside or over the drums, these rings being supplied with six or eight set screws so that the screw point may be brought into contact with the brake-drum metal and prevent this chatter. When these rings are used and properly applied, they will help to prevent the distortion

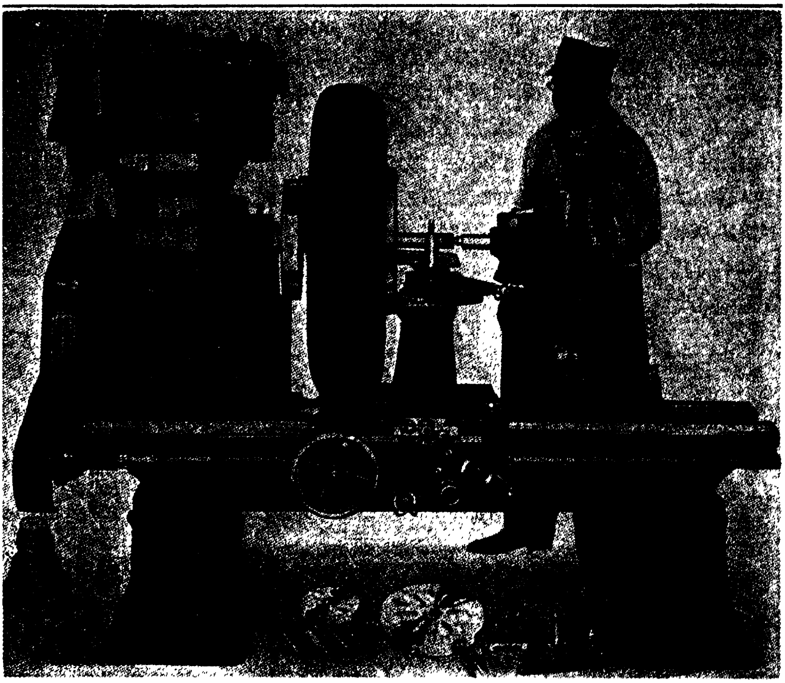


Fig. 41. South Bend Silent-Chain Motor-Driven Brake-Drum Lathe, with Wheel and Drum in Position for Turning

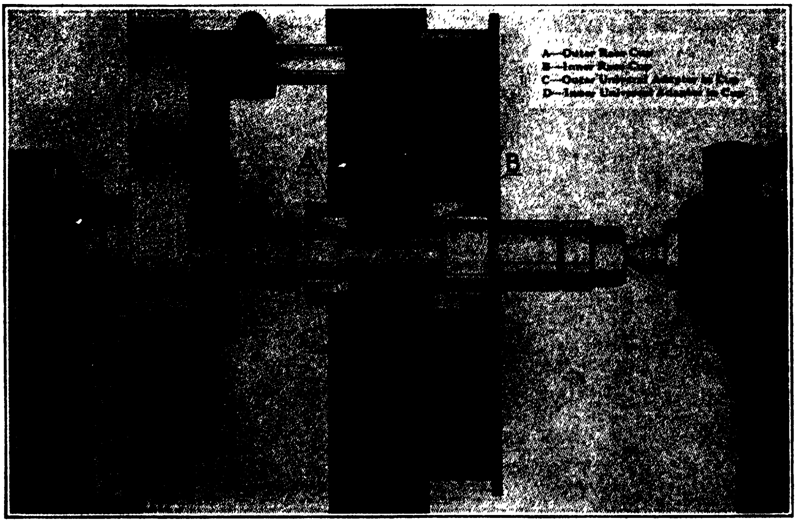

A—Outer Race Cup
B—Inner Race Cup
C—Outer Universal Adapter in Hub
D—Inner Universal Adapter in Cup
B

Fig. 42. South Bend Special Self-Centered Mandrel

of the brake drum under the pressure of the turning tool. On the other hand, careless operation of them may result in distortion of the brake drum and when the ring is removed after the job has been turned, the drum will spring back to its original form and be found to be out-of-round.

Uses for Brake Lathes. There are a great many jobs around the average garage which may be performed by a lathe. These range all the way from small work, such as commutator turning on the generator armature to differential case truing, flywheel ring-gear replacement, wheel-hub flange truing, balancing wheels with tires assembled, and so on. With this very wide range of probable jobs, the owner of a general garage will need to give thought to the ability of the machine selected to cover the range of work. If the machine is being purchased for a special shop, such as do brake work only, the more highly specialized machines will no doubt make the greatest appeal both from the point of cost and economy of floor space and operation. If the shop work is more general, the machine which more nearly approaches the standard type of screw-cutting lathe would be more serviceable.

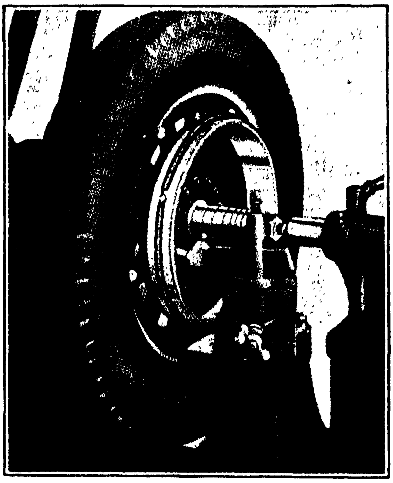


Fig. 43. Truing an Internal Brake Drum Mounted on a Straight Mandrel with Universal Bearing Adapters Mounted between Centers on the Lathe — Drum Size 17 Inches

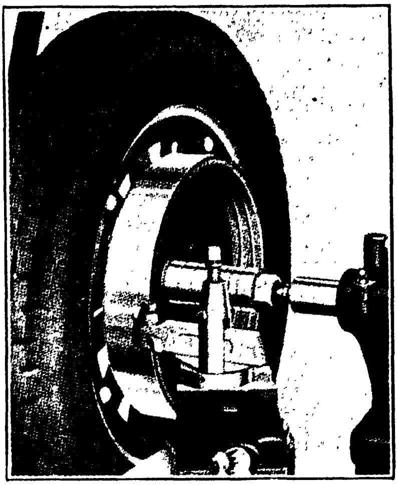


Fig. 44. Truing an External Brake Drum Mounted on a Straight Mandrel with Universal Bearing Adapters between Centers

AIR BRAKES

The air brake has been fitted to automobiles over a considerable period of years and every mechanic should know the principles involved in the air brakes. There are two types of brakes. One type operates on the principle of compressed air, that is, it works above normal air pressure. The other type, which is sometimes spoken of as a booster brake or vacuum brake, works on the vacuum principle, Fig. 45, and utilizes a pressure lower than the normal 14.7 air pressure.

Pressure System of Air Brakes. In the case of the pressure system, which is used on some busses and trucks, an air pump is provided on the engine which is used to compress air and force it into the air tank. This air tank has a sufficient capacity to allow for a reserve above that normally required. A relief valve permits the pump to operate continually without the tank reaching too high a pressure.

When setting the brakes, the operator merely opens the air valve, which permits the air under pressure to be admitted to the air cylinders. These air cylinders are not necessarily in the form of a cylinder such as is used in the hydraulic brakes, but are rather in the form of a housing within which a flexible diaphragm has been mounted. In this diaphragm is located the piston, which has a movement of only a few inches at the most. The pressure admitted to the cylinder forces the diaphragm against the piston head so that the piston rod is forced outward, and thus the braking action is secured. Fig. 46 illustrates this principle. Naturally considerable force is available for braking, since the operating pressure may be as high as 100 pounds per inch.

Vacuum System of Air Brakes. The vacuum principle has been made use of in a considerable number of cases in reference to passenger-car brakes. In practically all instances the system is so designed as to act in conjunction with the normal pedal action; the main feature being that normal pedal action brings into use the air or booster brake.

The fundamental principle involved is simple to understand if the mechanic understands the normal air pressure and what a vacuum really means. Normal weight of air or normal air pressure

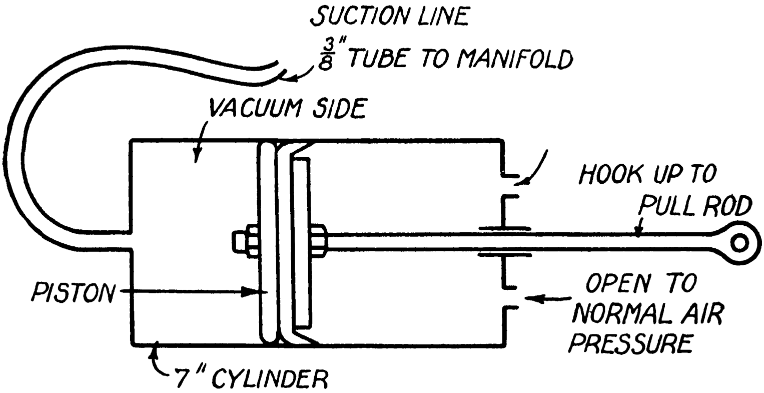


Fig. 45. A Simple Vacuum Brake

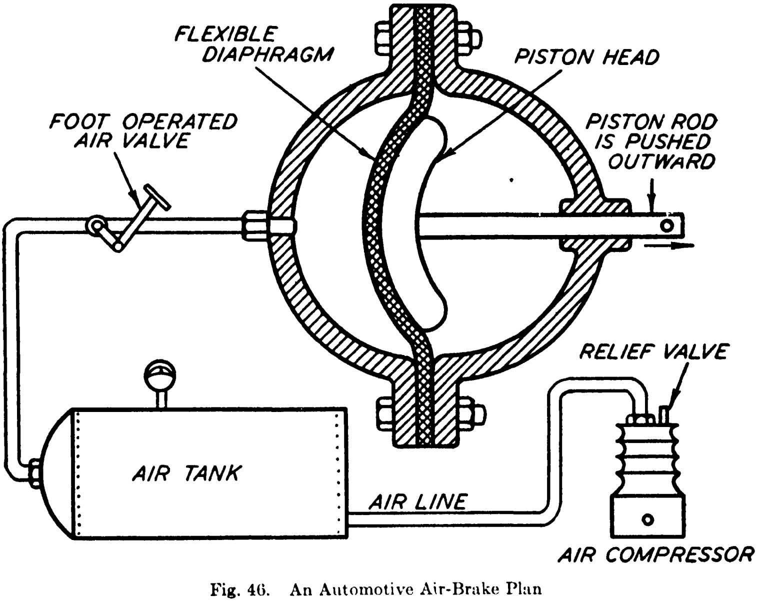


Fig. 46. An Automotive Air-Brake Plan

is 14.7 pounds per square inch at sea level. If the air is withdrawn from a cylinder and a piston is interposed between the external air and that portion of the cylinder from which the air is withdrawn, then a force equal to some part of the 14.7 pounds per square inch which is present forces the piston toward the point of vacuum. In no case is the full pressure of 14.7 pounds available for the simple reason that the vacuum is secured by connecting the vacuum side of the cylinder to the intake manifold of the engine. Possibly the highest pressure ever available would be around 10 to 12 pounds per inch. This would be only when the car is coasting along in high gear with the carburetor throttle fully closed. The pistons on the engine would be pumping the air away from the intake manifold and, with a closed throttle, very little air could be admitted so that a high vacuum would be secured. The force then available to set the brakes is the normal air pressure acting against the piston. Since but 10 to 12 pounds of pressure is available, the piston-head area is made relatively large. A 7-inch cylinder will develop a maximum pulling force of approximately 500 pounds.

Westinghouse Air Brakes. Fig. 47 shows the general arrangement and construction of the power unit, comprising a cylinder, piston, control valve, and operating levers, all enclosed in a dust-proof case.

The piston *P* in cylinder *S* is connected to the lower end of lever *C*. A short distance above this point at pin *L*, lever *D* is pivotly attached. Still higher up, pedal rod *E* is attached at point *N*, and the extreme upper end of lever *C* is mounted on pin *H*, with an appreciable amount of clearance.

Lever *D* is also mounted on pin *H*, but without clearance, so that *H* is a fixed fulcrum for this lever. Halfway between the fulcrum *H* and the pivoted connection to lever *C*, at pin *M*, is attached the rod *F* leading to the standard brake mechanism.

Brake application valve *A* and brake release valve *B*, normally held to their respective seats by a common spring, are caused to operate through the movement of the upper portion of lever *C*, suitable connection being made by connecting rod *J* and control valve rocker arm *K*.

A brief study of the sectional drawing, Fig. 48, will serve to reveal the manner in which the manual and power forces are com-

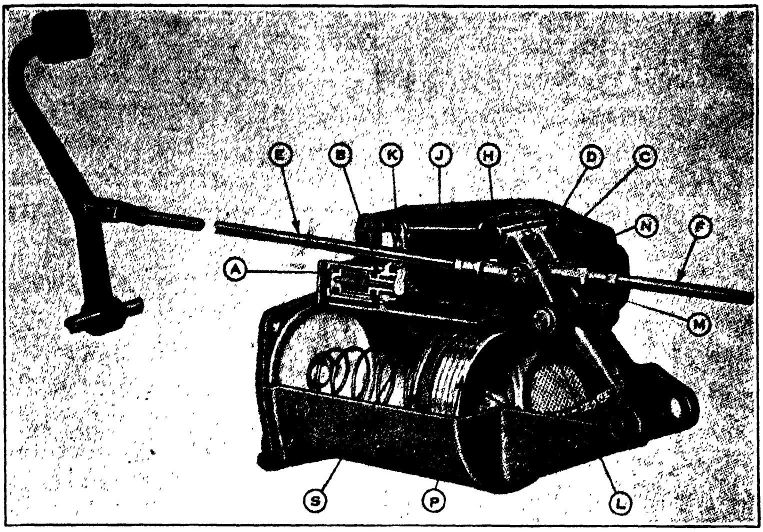


Fig. 47. Section View of Westinghouse Air Brake, Showing Construction

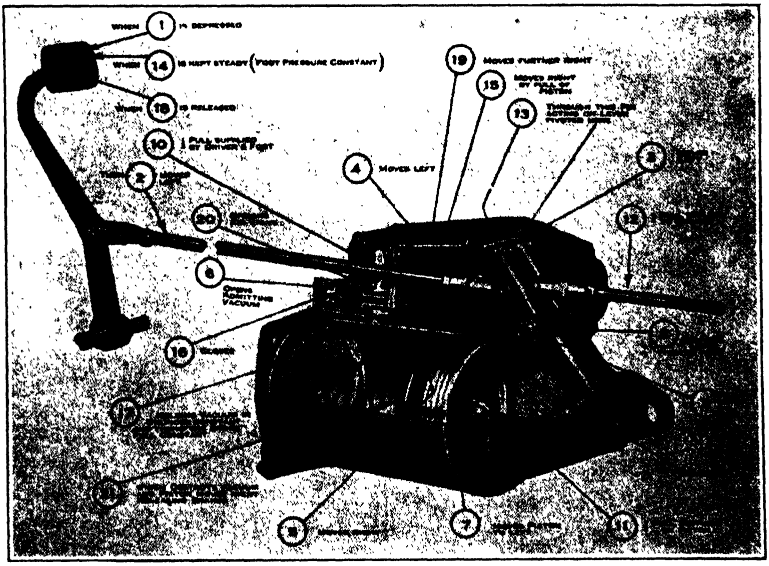

When 1 is depressed
When 14 is kept steady (Foot pressure constant)
When 18 is released
10 Pull supplied by driver's foot
2
20
8 Opens admitting vacuum
16
17
21
4 Moves left
19 Moves further right
15 Moved right by pull of piston
13 Through this pin acting on lever pivoted here
3
12
9
7
11

Fig. 48. Section View of Westinghouse Air Brake, Showing How It Works
When reading this illustration, start with the numbers in circles and follow from 1 through to 21 in order.

bined. With all parts in normal brake-release position, depression of the brake pedal exerts a pull on lever *C*, Fig. 47, through the rod *E*. The first movement of lever *C* will be at the upper end, so that it will move to the left to the extent of the clearance about pin *H* and incidentally exert a certain pull on the brake rod *F*. As rod *J* is attached to lever *C* without clearance, it causes the control valve *A* to be moved from its seat immediately, thereby connecting the source of vacuum with the power cylinder *S*. The partial vacuum that is always present when the engine is running is then permitted to act on piston *P* and cause it to exert a pull on the lower end of lever *C*. Lever *C* moves about point *N* as a fulcrum and advances lever *D*, rotating about *H* as its fulcrum. The movement of lever *D* exerts an additional pull on rod *F* and consequently on the brake mechanism.

It should be carried in mind that during the movement of power piston *P*, lever *C* is rotated about fulcrum *N* and that this fulcrum point is held by the pressure of the driver's foot on the brake pedal. The lever proportions, however, are such that the effort of the driver is a small fraction of the total brake effort. However, it holds a constant ratio throughout the entire power range.

It will be apparent that lever *C* has more than one fulcrum and that they are fixed only during the time a certain condition prevails. During the time the operator's foot pressure on the pedal is increasing, the lever fulcrums about some lower point and causes a partial takeup in the brake rigging and also the opening of valve *A*. When the operator's foot becomes stationary, lever *C* fulcrums about foot pull rod connection *N*, while the power cylinder increases the pull on the brake rigging and valve *A* is returned to its seat. In this manner a lap position is established.

An increase in braking effort is brought about by a repetition of the above, while a complete or gradual reduction is made by simply easing off on the foot pedal in the usual manner. Under these conditions the power portion of lever *C* becomes a fulcrum and the upper end moves to lift valve *B* from its seat. Atmosphere then replaces the partial vacuum and piston *P* is advanced toward release position by suitable release spring. The proportional balance between the foot pedal and power unit effort is maintained throughout the release just as it is during the entire application.

HYDRAULIC BRAKE DESIGN

One of the earliest applications of the hydraulic principle to the work of setting the brake shoes to the brake drums was in the case of the Duesenberg car, Fig. 49, which made use of the principle in connection with four-wheel brakes of the internal expanding type about the time that four-wheel brakes were first introduced in the United States.

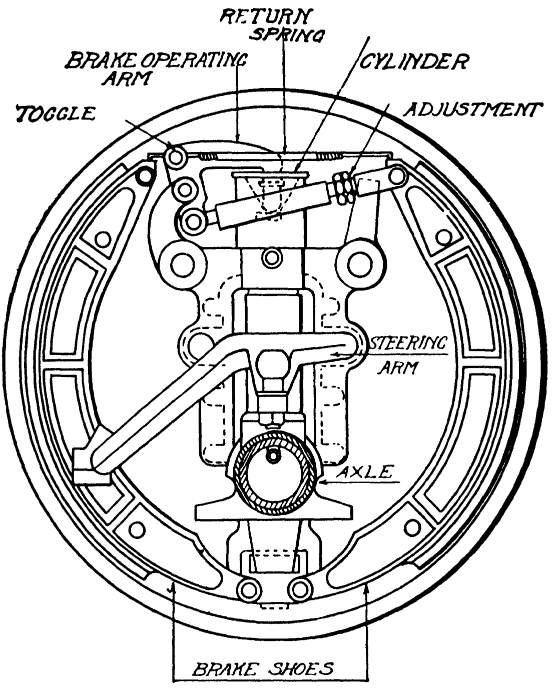


Fig. 49. Duesenberg Internal Expanding Front-Wheel Brakes Are an Early Example of the Application of the Hydraulic Principle

There are two scientific principles made use of in the hydraulic brake system. The one is with reference to the incompressibility of liquids; and the other is with reference to the pressure, which is induced on any liquid which is confined, being exerted in like amount in all directions and against all surfaces with which any of the confined fluid is in contact.

Since liquids are non-compressible, they are an ideal medium for transmitting power, Fig. 50, under certain conditions. While

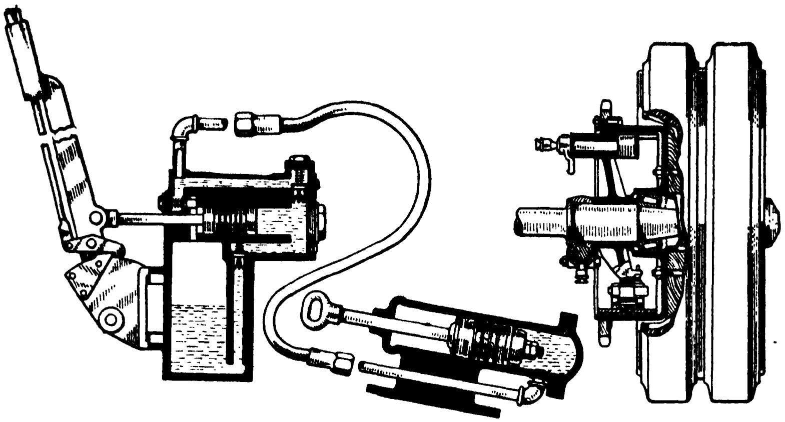


Fig. 50. Layout of Hydraulic Brakes Used on Knox Tractor, Which Shows the Master Cylinder, the Fluid Line, and One Wheel Cylinder

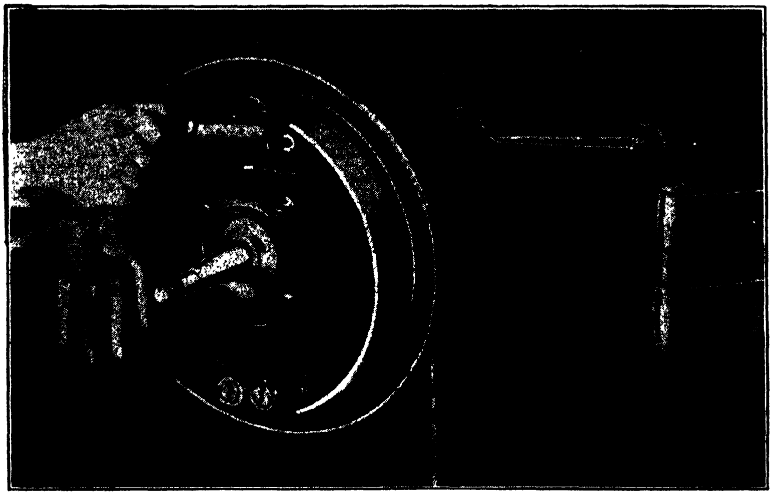


Fig. 51. Demonstrating the Hydraulic Principle on Dodge Car

air may be compressed into a fraction of the normal space it occupies, as in the case of compressing air and fuel in the combustion chamber of the engine, the same is not true of liquids. If water, for instance, finds its way into the cylinder and the piston is brought up on compression stroke with both valves closed, the engine cannot be turned over. The water stops the travel of the piston just as effectively as though there was a chunk of steel within the cylinder. The only difference is this—the water will slowly leak past the valves or piston rings while the chunk of steel would stay in position indefinitely. Herein then is a lesson for those who service hydraulic brakes. A leak at any point in the system results in loss of holding power or loss in efficiency of the system.

The scientific principle with reference to equalized pressure on a confined liquid is illustrated in the case of the rubber glove shown in Fig. 51, where it is shown held close to the wheel cylinder of the Lockheed internal expanding brake system. When the hand holding the glove is squeezed shut on the liquid in the glove, equal pressure is induced in each of the fingers. The liquid does not compress, but the rubber glove stretches and the fingers grow larger due to the internal pressure, and the amount of pressure per square inch is equal for each and every square inch within the glove having any of the liquid under pressure in contact with it.

Now in the case of the hydraulic brake system, all of the tubes and cylinders are made of non-stretching fabrics or metals. The only parts which will give to make room for the liquid, which is sent from the master cylinder through the brake lines, are the pistons within the wheel cylinders. One of these is shown in section in Fig. 52.

Just as the liquid under pressure flows to the fingers of the glove, so the brake fluid under pressure flows to each of the four brake cylinders and exerts exactly the same amount of pressure per square inch on each of the pistons. The hydraulic system may be said to be self-equalizing. Such inequalities as may exist in the braking system of any hydraulic brake equipped car would have to be due to the size of the wheel cylinders. Since, as a rule, these are all of the same size, the system is equalized.

It does sometimes happen that not all brakes are equally effective, but this is usually due to differences in the adjustment of the brake shoes, the quality of the lining, water or grease present on some of the linings, the drums being out-of-round, scored, or otherwise rendered unequal, return springs not equal, parts corroded or damaged so that they do not function properly, or other more or less mechanical faults that may have developed.

The hydraulic four-wheel brake system in the case of the De Soto car is illustrated in Fig. 53. The master cylinder *A* is connected to a copper tube or line which runs to the rear a bit where it joins three feed lines, one of which feeds the two rear cylinders, and the other two, marked *C* and *D*, feed the two front wheel cylinders. The pressure induced when the foot pedal is forced downward, Fig. 54, causes the brake fluid to flow with equal pressure along the lines *B, C, D,* and the cross lines *E* and *F* at the rear, Fig. 53, with the result that the eight pistons within the four-wheel cylinders are forced outwardly with even pressure just as the four fingers of the glove were equally expanded.

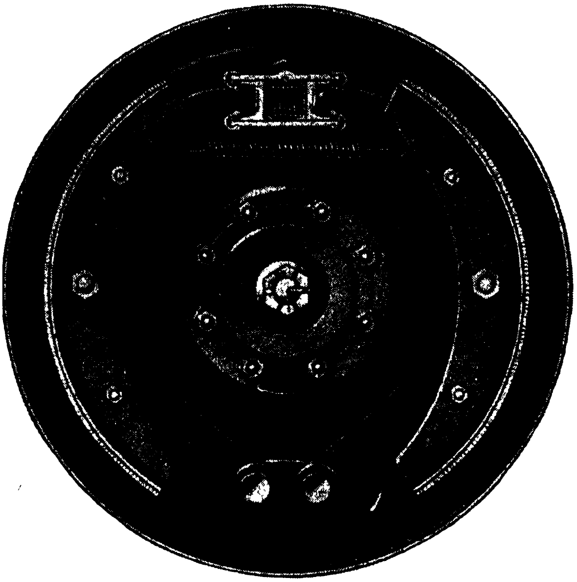


Fig. 52. Showing the Simple and Sturdy Brake-Shoe Construction Employed in the Hydraulic Four-Wheel Brakes of the Internal-Expanding Type on the Chrysler Imperial "80"

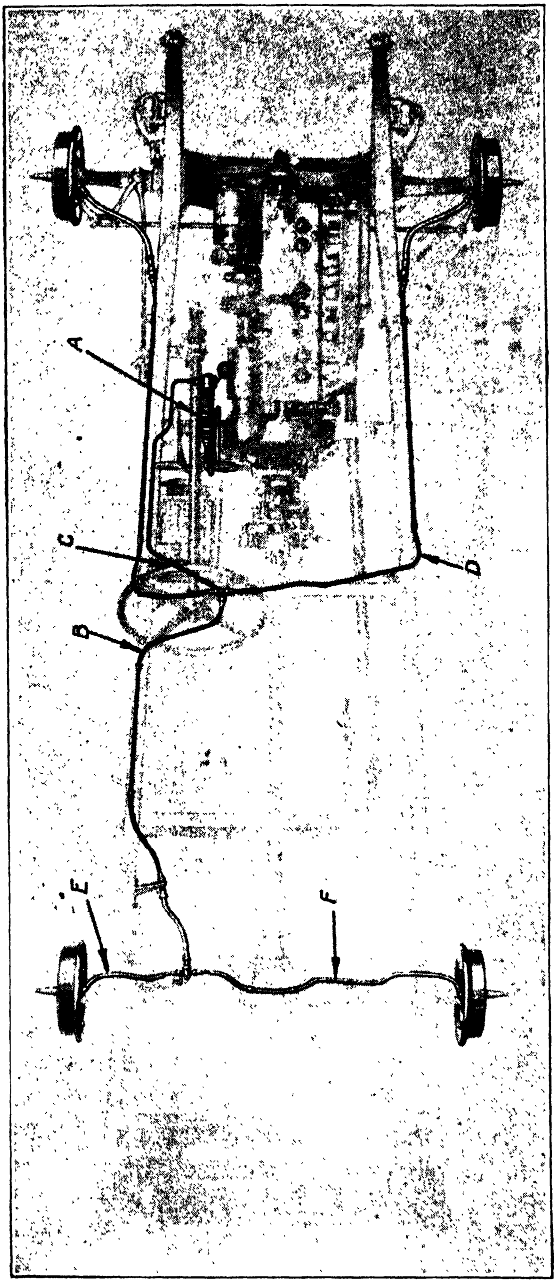


Fig. 53. Hydraulic Four-Wheel Brake System

Now since each piston is in contact with the upper end of a brake-shoe rigging, it will be seen that the outward movement of the eight pistons move the eight brake shoes outwardly in a simultaneous fashion so that all eight of the brake shoe linings come into contact with the wheel brake drums at one time with equal force so that the braking effect, all other conditions being right, will be equally distributed to each of the four wheels and tires.

The early application of the hydraulic principle was with reference to the external contracting brake band similar to the one shown in Fig. 55. In this figure, *A* is the flexible but non-expanding tube used to connect the cylinder *B* with the brake fluid line and the master cylinder. As the pistons within the wheel cylinder are forced outward, the brake band is set to the brake drum by the action of the two bell cranks, one of which appears at *C*. The bell crank in this case merely serves to change the pushing action of the pistons to a pulling action at the ends of the brake band so as to draw them together against the brake drum, which is just the reverse of the

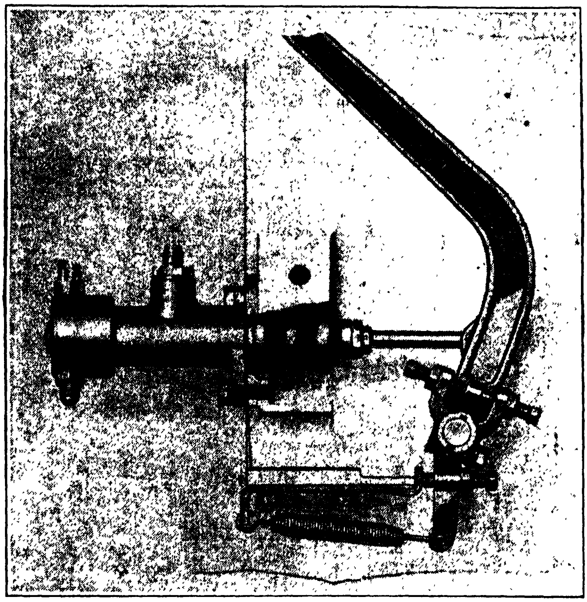


Fig. 54. DeSoto Brake Pedal and Master Cylinder Hook-Up

later development of the internal expanding action. The pistons are returned to position by the action of the two springs *D*.

Wheel Cylinders. Over a period of years there has been much improvement in design and quality of materials used in the hydraulic braking system. Fig. 56 illustrates the fundamental principles of wheel cylinder design which have held for many years. The cylinder, which is a casting, has such lugs provided and machined as may be necessary for mounting it and other parts to it. It is open at each end and receives within it the two pistons shown lying below it. These pistons are aluminum alloy and are provided with a specially prepared cup washer on their inner ends. These cup washers are designed to work in connection with the specially prepared brake fluid. When the fluid and cup washers are used together, the best

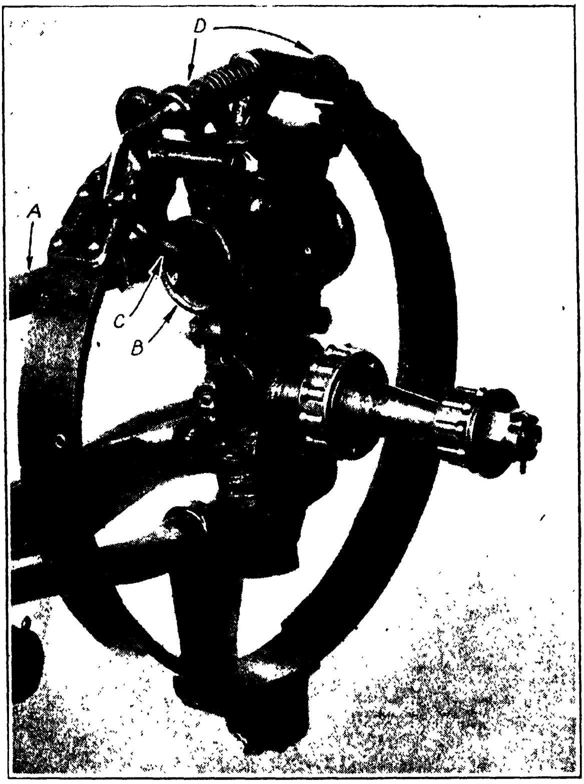


Fig. 55. Constructional Feature of Lockheed External-Contracting Hydraulic Brake

possible satisfaction in the way of braking efficiency is secured. The use of other than the proper brake fluid may result in rapid deterioration of the cup washers, with the result that brake failure occurs.

Master Cylinders. The master cylinder is mounted close to the brake pedal and contains the piston which is connected to the brake pedal. One form of the master-cylinder design is shown in Fig. 57. The piston is shown above it. Two brake fluid line fittings *A* are used to connect up the wheel cylinders much after the fashion of the illustration in Fig. 58, which shows the brake pedal *A*, the master cylinder *B*, the supply cylinder and pump *C*, a three-shoe internal-expanding brake rigging at *D*, and an external contracting band and wheel cylinder assembly at *E*. This illustration depicts all of the essential units in a hydraulic system.

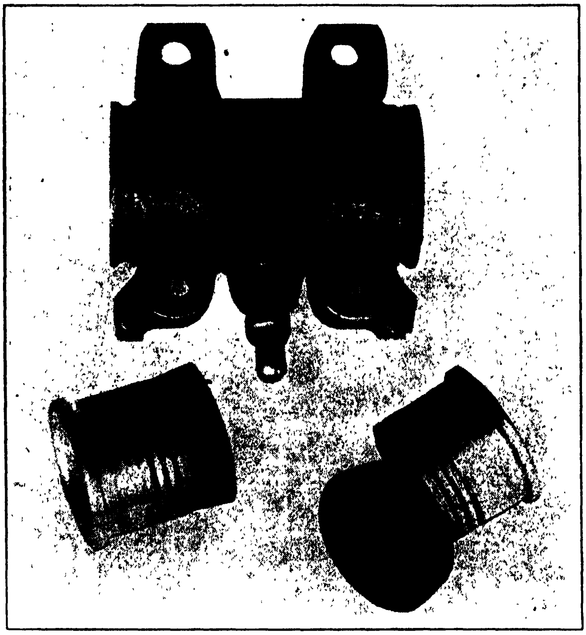


Fig. 56. Wheel Cylinder of Hydraulic System
Aluminum pistons and special cap washers are shown removed from cylinders.

Three-Shoe Internal-Expanding Rigging. When the brakes are applied with the wheel drum turning in the direction of the arrow, Fig. 59, it will be seen that the shoe *Y* will be carried around and

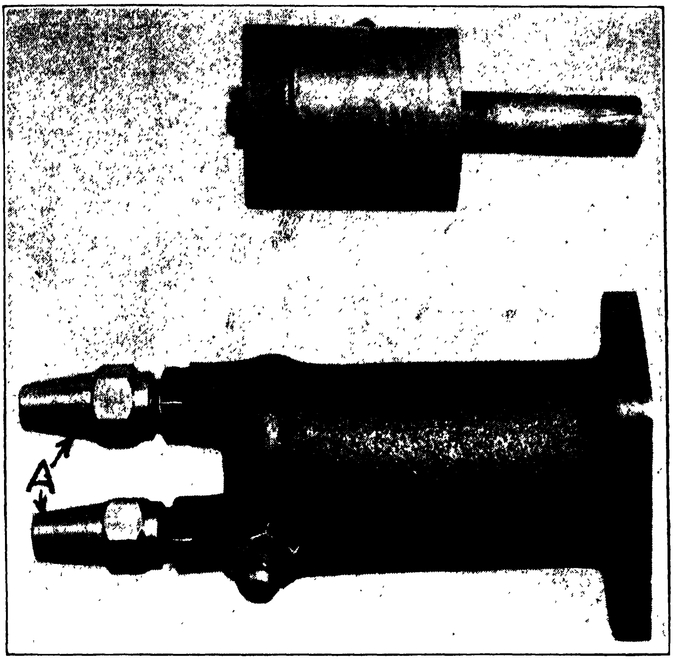


Fig. 57. Lockheed Master Cylinder and Piston of Hydraulic System

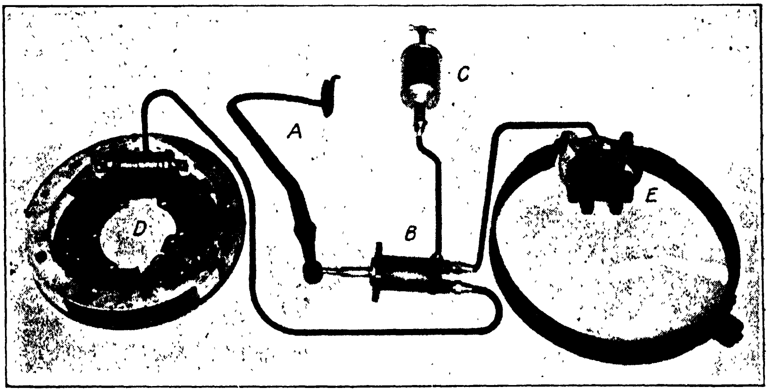


Fig. 58. Main Parts of Lockheed-Wagner Hydraulic Brakes

against the shoe *Z*, with the result that the forward thrust of the shoe *Y* adds greatly to the frictional thrust of *Z;* and because of this servo or self-setting action, the amount of pedal pressure required to set the brakes is lessened.

Supply Cylinder or Tank. It is necessary to provide for a reserve supply of brake fluid and to keep this supply tank properly filled in order that the system may not fail owing to the lack of a proper amount of brake fluid. It is also necessary to see that the fluid within the cylinder never gets too low so that the air will find its way into the master cylinder, fluid lines, and wheel cylinders. Air is compressible and gives under pressure. A slight amount in the hydraulic system and the whole system is rendered ineffective. In case air does get into the system due to lack of proper level in the supply tank, then the system must be bled.

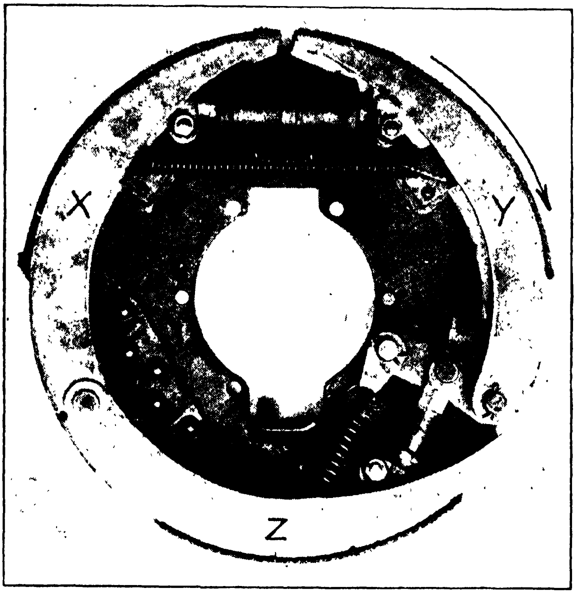


Fig. 59. An Internal-Expanding Hydraulic Brake Shoe and Cylinder Device

Supply cylinders or tanks are not always separate and mounted on the dash, as in the case of the tank shown in Fig. 60. The practice with many of the car builders is to make use of the combined supply tank and master cylinder unit illustrated in Fig. 61.

Where the individual tank is used, the supply of brake fluid is pumped from the supply cylinder into the master cylinder as needed by means of the pump and valve arrangement shown in Fig. 60. This pump has a small piston on its lower end which fits into the reduced portion of the supply cylinder. The threaded portion below the piston is part of the valve used to seal the supply tank and brake system when the pump is not in use. Before the pump may be used, the handle must be turned backward to unscrew the valve. Next the necessary amount of brake fluid is pumped into the system by working the pump handle up and down. When the brake pedal stands the proper distance from the floor board with the brakes set, the pump is screwed down and the taper or needle valve seats and seals the system.

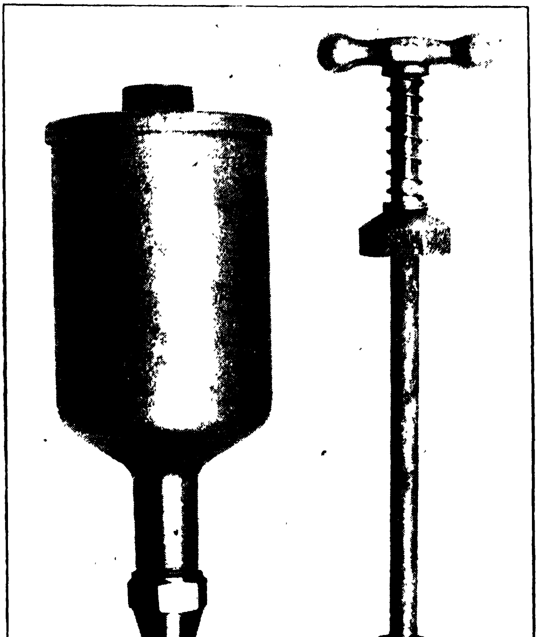


Fig. 60. Supply Cylinder and Pump

Lockheed Hydraulic Four-Wheel Brake. The Lockheed system, Fig. 61, consists of a supply tank, a master cylinder, copper tubing, leading from the master cylinder to flexible hoses which connect the copper tubing to the brake cylinders. Simple in construction, the brakes depend only upon the fundamental displacement principle of hydraulics for their operation and equalization.

The master cylinder is fitted with a piston, and the wheel cylinders are fitted each with opposed pistons; all of which are provided with cup packings of moulded composition rubber which act as a seal to maintain pressure and prevent loss of the brake fluid.

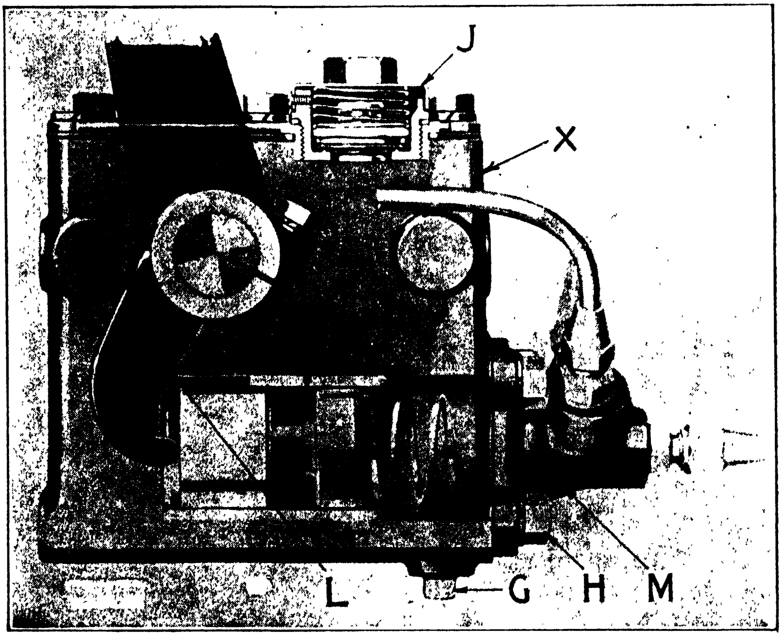


Fig. 61. Sectioned View of the Lockheed-Wagner Master-Cylinder Housing with the Supply Tank, Foot Pedal, and Brake Fluid Tubes

The brake pedal, when depressed, moves the piston within the master cylinder, thus displacing the brake fluid from the master cylinder through the copper tubing and flexible hose connections into the four wheel cylinders.

The brake fluid enters into each of the wheel cylinders between their opposed pistons, causing them to move outwardly against the brake shoes, thus moving them into contact with the brake drums.

As pressure on the pedal is increased, greater hydraulic pressure is built up within the wheel cylinders, and consequently greater force is exerted against the ends of the shoes.

The very principle of hydraulics dictates that pressure exerted upon a fluid is transmitted equally to all surfaces. It is therefore obvious that the pressure applied at the foot pedal is equally distributed to each of the four-wheel cylinders, and that the pressure exerted against the brake shoes must also be equal.

When pressure on the foot pedal is released, the return springs on the brake shoes retract and return the wheel cylinder pistons to their normal or "off" position, thus forcing the brake fluid back through the flexible hoses and copper tubing to the master cylinder.

Master Cylinder. The master cylinder, known as the compensator type, differs somewhat from the conventional type, being so designed that it automatically maintains a constant volume of fluid in the system; compensates for expansion or contraction of the fluid due to temperature changes; and replenishes any loss resulting from slight leaks.

The master cylinder *M*, Fig. 61, is contained within the supply tank *X*, upon which is mounted the clutch and brake foot pedals; the whole unit in turn is mounted directly to the car frame. This supply tank serves to carry the reserve supply of fluid. The master cylinder is submerged in the fluid, thereby protecting the system at this point from any danger of taking in air, dirt, or water.

Located so as to be directly forward of the master piston cup when the piston is in the "off" position is a port hole through the wall of the cylinder *B*, Fig. 62. A rise in temperature causes the fluid in the braking system to expand, the excess by-passing the port to the supply tank. A drop in temperature causes the fluid to contract. This loss is replenished from the supply tank through the port. Thus a constant volume of fluid is maintained in the system.

From the foregoing it is apparent that the brake pedal must be set so that the master piston cup is back or clear of the port when the brakes are in the "off" position. The return of the master cylinder piston to its "off" position is accomplished by a return spring *C*, Fig. 62, enclosed within the master cylinder.

In the head of the master cylinder, held in place by a return spring, is a combination inlet and outlet check valve. When the brakes are applied, the master-cylinder piston is pushed forward, which opens the outlet check valve *D*. The fluid is forced through it into the system. When the brake foot pedal is released, the master-piston return spring forces the piston back to its "off" position against its stop. At the same time the wheel cylinder piston return springs are forcing the fluid back through the inlet check valve *F*, until the fluid pressure balances the weight of the master-cylinder return spring, when the inlet valve closes.

Should the return of fluid be insufficient to equal the displacement caused by the return of the master piston, a vacuum is created in the master cylinder sufficient to cause the master piston cup *A* to turn in at the lip and allow the fluid to by-pass from the supply tank in to the master cylinder. Any excess fluid by this means introduced into the system will pass freely into the supply tank through the port when the master cylinder piston returns to its "off" position. The combination valve functions differently when bleeding or filling the system with brake fluid.

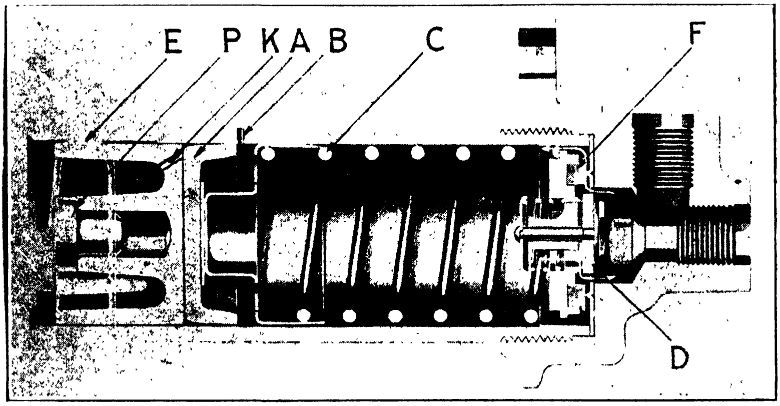


Fig. 62. Master Cylinder of the Lockheed-Wagner Hydraulic Braking System

Wheel Cylinder. The wheel cylinder, mounted rigidly to the dust shield, is fitted with opposed pistons, the stems of which are connected to the brake-shoe ends. The open ends are fitted with rubber boots to protect the cylinder from foreign substance. The fluid enters the cylinder between the opposed pistons. At the uppermost position and between the opposed pistons is the bleeder valve required for expelling the air when filling the system.

Supply Tank. The supply tank is a simple reservoir and functions to feed the fluid system. The filler plug *J*, Fig. 61, in the tank is fitted with a breather valve. When the system is inoperative, the breather valve seals the tank, preventing the evaporation of the alcohol content in the fluid.

Service Instructions. The supply tank should be inspected at least once a month and if the fluid level is found to be low, it is an indication of a leak at some point in the system.

No adjustment is required for equalization—the pressure delivered to the shoes will be the same at all wheels. Adjustment is only necessary to compensate for wear of the brake lining. The frequency of such adjustment will depend upon the character of service to which the brakes have been subjected.

While it is a fact that the pressure delivered to the shoes will always be equal, yet paint, grease, oil, or other foreign substance on the brake lining will change the coefficient or friction of the lining to the point where the brakes will be unequal. This inequality can only be remedied by thoroughly cleaning the lining with gasoline or alcohol and roughening the surface with a file or wire brush. If, however, the lining is so saturated with grease or oil that cleaning will not correct the unequal braking effect, it will be necessary to reline the brake shoes.

Brake Adjustments. When lining wear has reached a point where the foot pedal almost goes to the floorboard, it becomes necessary to adjust the brake shoes into closer relation to the brake drums. Adjustment is made by rotating the adjustment cam *A*, Fig. 63, against the stop pin *B* on the shoes. The tension of the friction spring *D* automatically keeps the cam locked in any position.

To Adjust Brakes. Raise the car on the jack until the wheel is free. Rotate the adjustment nut *C*, Fig. 64, with a wrench until the brake shoe comes into contact with the drum. Now back the adjustment off slightly until the wheel rotates freely without any appreciable drag. Repeat this operation on all eight brake shoes. In Fig. 64 it will be seen that to adjust the shoe into close relation to the drum, the adjustment nut must be turned toward the rim of the wheel when the wrench handle is pointing up. The brake shoe anchor pins *E*, Fig. 63, are eccentric and also points of adjustment but these are set at the factory and should not be changed.

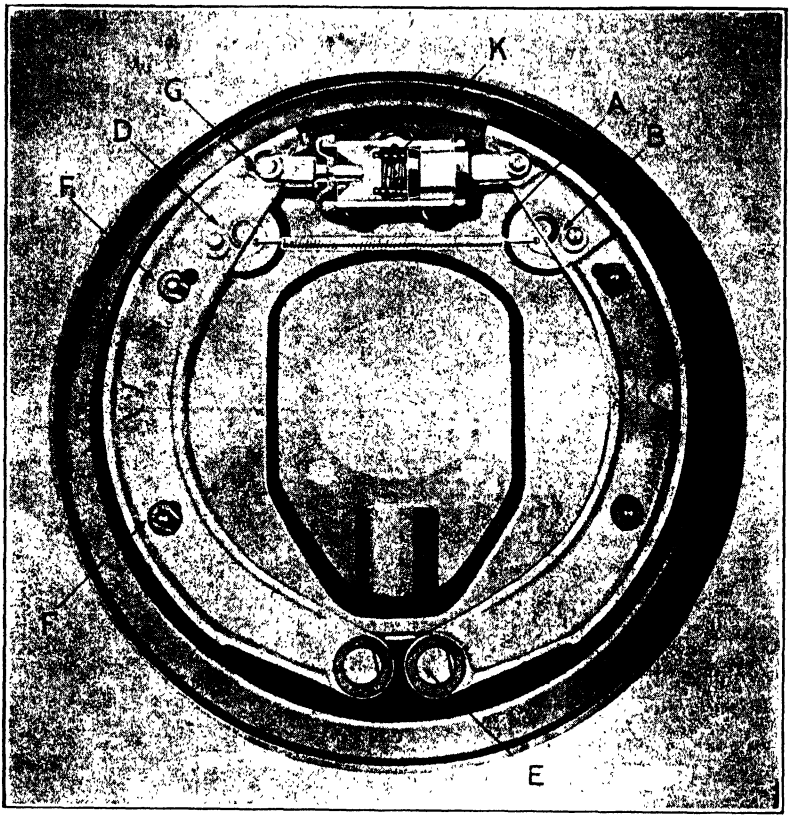


Fig. 63. Wheel Cylinder and Brake Rigging of the Lockheed-Wagner Hydraulic Braking System

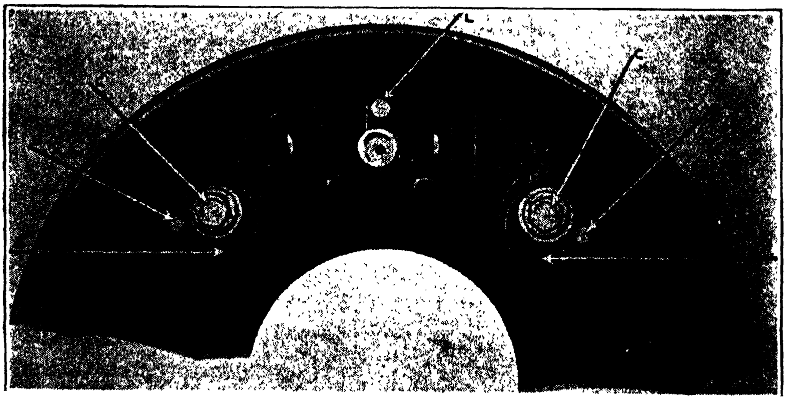


Fig. 64. Adjusting Chart for Lockheed-Wagner Internal-Expanding Brakes

Relining Brakes. When relining brakes, it is imperative that the same kind of lining be used on all four wheels; otherwise the brakes on the individual wheels will not be equally effective in their action.

To Remove Brake Shoes. Remove the *C* washers from the anchor pins *E* and guide pins *F*, Fig. 63. Then unhook the brake shoe return spring, after which the shoes may be pulled off. In assembling, these operations are reversed.

To Remove the Front-Wheel Cylinder. Disconnect the copper tubing from the hose union *A*, Fig. 65, at the frame, then remove the nut *B* and the lockwasher, then the hose union may be removed from the bracket. Rotate the cam adjustments to bring the shoes clear of the wheel cylinder connecting links. Removal of the two cap screws *J*, Fig. 64, holding the cylinder to the brake dust shield, allows the cylinder to be withdrawn from the shield.

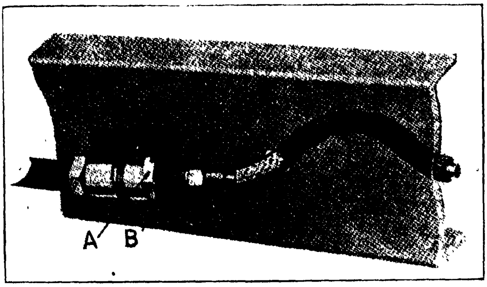


Fig. 65. Bracket Supporting the Hook-Up Union between the Copper Tubing and the Flexible Tube

To Remove the Rear-Wheel Cylinder. Follow the instructions for the front cylinder except that the copper tubing must be disconnected at the cylinder inlet.

To Remove the Wheel Cylinder Cups. Remove the rubber boots on either end. Withdraw the pistons by inserting a hook in the hole in the skirt of the pistons. The spiral spring placed between the wheel cylinder cups serves to keep the cups in contact with the pistons at all times.

To Remove the Master Cylinder from the Supply Tank. Take out the drain plug *G*, Fig. 61, in the bottom of the supply tank and draw off the fluid. Disconnect the copper tubes and remove the four cap screws *H* which hold the cylinder in place, and withdraw the cylinder. Remove the lockwire from the end of the cylinder, allowing the master piston, cup, return spring, and the combination valve to be taken out. It should not be necessary to disassemble any cylinder unless it is found to be leaking fluid past the cup.

The cylinder and cup should be cleaned with crocus cloth and washed with alcohol. Do not use kerosene, gasoline, etc. The bore should be free from any score marks, rust corrosion, or pits. It is best to use new cups when servicing a cylinder. Cup and piston should be dipped in brake fluid before inserting into the cylinder.

Bleeding the System. Bleeding the system is necessary only when some part of the hydraulic mechanism has been disconnected. When bleeding, depression of the foot pedal forces the fluid from the master cylinder through the outlet combination valve and thence to the wheel cylinders through the tubing. Since there is no pressure within the system, the master piston return spring will hold the return valve closed, creating a vacuum within the cylinder which causes the cup to collapse at the tip and allow fluid to by-pass from the supply tank, thus refilling the master cylinder.

Working the foot pedal gives a pumping action which forces fluid through the tubing and out at the wheel cylinder, carrying with it any air that may be present.

To Bleed the Line. Remove the floorboard and unscrew the filler plug *J*, Fig. 61, in the top of the master-cylinder supply tank, exercising care to prevent any dirt getting into this opening. Fill the supply tank with Lockheed brake fluid.

A bleeder screw or valve *L*, Fig. 64, projects at a slight upward angle from the center of each wheel cylinder, the outer end of which is provided with a hexagon shoulder to receive the wrench. The passage through this valve is threaded to receive the cap screw, the head of which is also hexagon shaped. Remove the cap screw with a wrench, after which the nipple at the end of the rubber drain tube may be screwed in place, Fig. 66.

Open the valve about three-quarters turn of the wrench and allow the free end of the rubber tube to hang into a clean container, such as a fruit jar. Depress the foot pedal by hand, allowing the return spring to return the pedal to its released or "off" position. Approximately ten strokes of the pedal will be necessary to bleed each wheel cylinder.

When bleeding, be sure to keep the master-cylinder supply tank more than half full of fluid; otherwise air will be drawn into the system at this point, necessitating re-bleeding. As each wheel cylinder is bled, the bleeder valve is shut off tightly with a wrench; the tube is removed and the cap screw replaced. When the bleeding operation is completed, refill the supply tank and replace the filler plug and screw it down tight.

Caution. Do not use any substitute for Lockheed brake fluid. Lockheed brake fluid is a mixture of neutralized castor oil and denatured alcohol treated with chemical reagents to counteract the action of the fluid on the metal and rubber parts of the system. A substitute may be lacking in these important factors and do much damage to the system. Do not allow grease, paint, oil, or brake fluid to come in contact with the brake lining. Do not clean rubber parts or inside of cylinders with anything but alcohol. Do not use kerosene or gasoline. Do not reline one wheel with a different make of lining than is used on the others, as you cannot expect equal braking effect if this is done. Do not allow the supply tank to be less than half full of brake fluid.

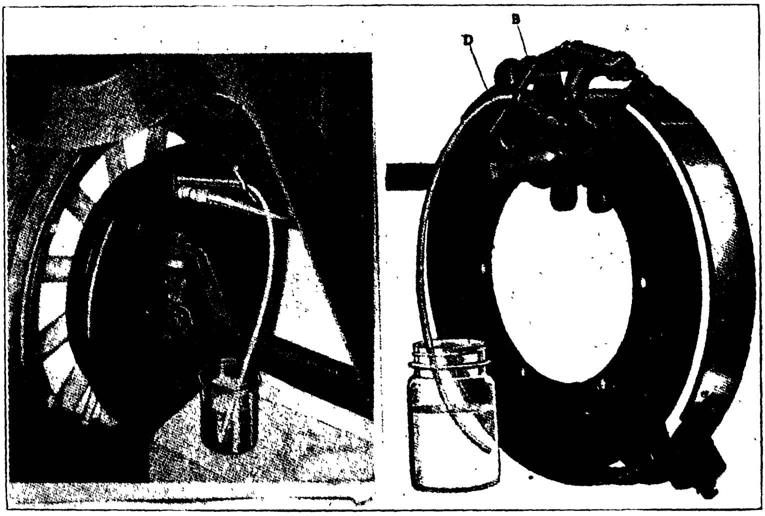


Fig. 66. Bleeding Wheel Cylinders to Remove Air Pockets

Bendix Three-Shoe "Servo" System. In this design the servo principle is secured by hinging the primary shoe to the secondary

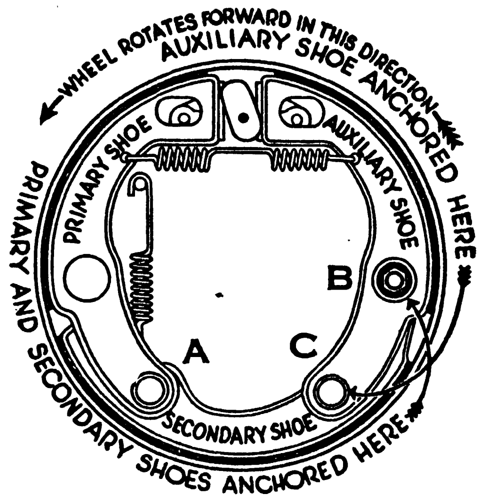

WHEEL ROTATES FORWARD IN THIS DIRECTION
AUXILIARY SHOE ANCHORED HERE
PRIMARY SHOE
AUXILIARY SHOE
B
A
C
SECONDARY SHOE
PRIMARY AND SECONDARY SHOES ANCHORED HERE

Fig. 67. Chart Showing the Design and Action of the Bendix Three-Shoe Servo Brake Shoes in the Drum

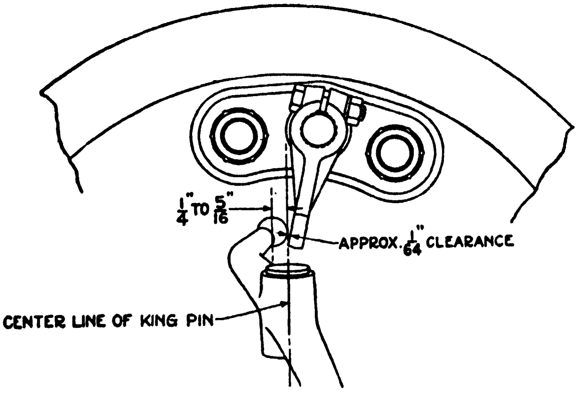


Fig. 68. Proper Alignment of Parts for Lever Type Bendix Front-Wheel Brakes

shoe at point *A*, Fig. 67. The primary and secondary shoes are linked together and are pivoted to the backing plate at the point *B*, by means of an anchor pin.

The auxiliary shoe, which is the third shoe, is hinged to the backing plate by the pin *C*, so that it pivots from this pin. The three shoes are held in a contracted position and free from the drum by means of the springs shown.

The servo action is secured when the rotating wheel carries the primary shoe with the brake drum when the brakes are applied. Since the thrust of the primary shoe must be transmitted through the secondary shoe and around to the anchor pin *B*, it will be seen that a powerful thrust outward is given the secondary shoe so that the brake pedal action is multiplied over and over.

Owing to the design which features the cross-anchoring overlapping joint construction of the brake shoes, over ninety per cent of the possible braking surface is utilized. When the brakes are applied, the complete surface of the lining on the three shoes comes into braking contact. This makes for long life of the brake lining.

A considerable variety of the braking controls have been evolved for use in connection with the Bendix systems. These are the Bendix lever control, the Bendix-Perrot control, the Bendix cable and conduit control, and the Bendix crank and link control. These are used at the option of the car manufacturer.

TROUBLE SHOOTING ON BENDIX DUO-SERVO BRAKES

Trouble	Remedy
Cars steering unevenly when the brakes are applied.	Balance both front and rear wheels. See that both front and both rear wheels will slide together; do not expect all four wheels to slide at the same time. NOTE: The design of the system of leverages in the hook-up mechanism of different cars is such that the percentage of braking power distributed to front and rear wheels is not the same. See that all spring clips are extremely tight. See that both front tires are inflated to the same pressure. Check the rear tires also. Examine to see that controls to both front brakes are well lubricated so that each works freely.
Brakes chattering when applied.	Tighten loose spring clips. Check and tighten the backing plates if found loose on the axle mountings.

TROUBLE SHOOTING—Continued

Trouble	Remedy
Brakes chattering when applied.	True up the brake drums if out-of-round more than .010 inch. (Do not remove the drum from the hub of the wheel.)
	If moulded linings are found greasy, clean grease from the lining with high test gasoline.
	NOTE: There is no sure or permanent cure for trouble from greasy brake linings except by replacement. Brake lining saturants should never be used. Grease cannot be successfully removed by burning the linings with a blow torch.
	Balance all brakes.
	Check the lining clearances and if not correct, make complete readjustment.
Brakes grabbing or locking when applied.	See that the lining is free from grease or oil.
	Adjust any loose wheel bearings.
	Tighten all spring clips.
	See that the anchor pins are located correctly and tightened extremely tight.
	Make sure the lining is tight on shoes.
	Check the brake drums to see that they are not out-of-round or loose on the wheel itself.
	Lubricate all bearings in the entire braking mechanism.
	See that the hook-up releases freely.
	Check and tighten the backing plates if found loose on axle mountings.
Brakes squealing when applied.	Check the brake drums to see that they are not out-of-round or scored.
	See that the lining and drum clearances are properly set up.
	See that the lining is not loose on the shoe. Tighten the rivets.
	Remove noticeable high spots on the surface of the linings with a file.
	See that the lining fits firmly to the shoe, with no bulging between rivets.
	Backing plates must be tight on flanged mountings.
	See that the wheel bearings are adjusted accurately.

TROUBLE SHOOTING—Continued

Trouble	Remedy
Brakes dragging when in a released position.	The brake shoes should be centralized in the brake drum. This can be accomplished by use of the eccentric adjustment. A check showing about .008 inch clearance at anchor end and about .014 inch clearance at screw adjusting end of each shoe will indicate that adjustments have been properly made.
	The brake drums being out-of-round can cause the brake to drag intermittently.
All the brakes but one holding.	Jack up the car and see if this one brake can be taken up more without causing the shoes to drag.
	Check the lining and drum clearances to see that the anchor pin settings are correct.
	See that the front control levers, when the brakes are released, are in their correct positions, as shown in Fig. 68.
	Refer to adjustment instructions for correct setting of rear control levers.
	Check for worn steering knuckle (front wheel).
	Remove grease from lining.
	See that the hook-up is well lubricated.

TRANSMISSION BRAKES

The transmission brake is ordinarily of the exposed type. In reality it is not a transmission brake but takes its name from its application to the propeller shaft just back of the transmission. Ordinarily the brake drum is pulled from the car with the transmission. Brakes when used in this position are used as emergency brakes and are connected with the hand brake. For a number of years the Franklin Motor Car Company made use of a brake drum in this location for the service brake. The Ford Model "T" car foot brake was connected with the transmission drum and was a real transmission brake. Some trucks and buses make use of drums located in connection with the transmission or propeller shaft for service brakes. In such cases the brake drums are very heavy and are designed for the dissipation of heat.

Care of Brake. The transmission brake has a very powerful action owing to the fact that the braking effort is multiplied many times over, due to the gear ratio between the pinion and ring gear.

However, the hand brake is used so seldom that it is frequently neglected so that when an emergency does arise, it is of little worth. Possibly the most frequent cause of transmission brake failure is the saturation of the brake lining with grease thrown off from the transmission. Brake lining so saturated either refuses to hold at all in case of an emergency or, if it does hold, is likely to generate so much heat that the oil starts to smoke and may even burn.

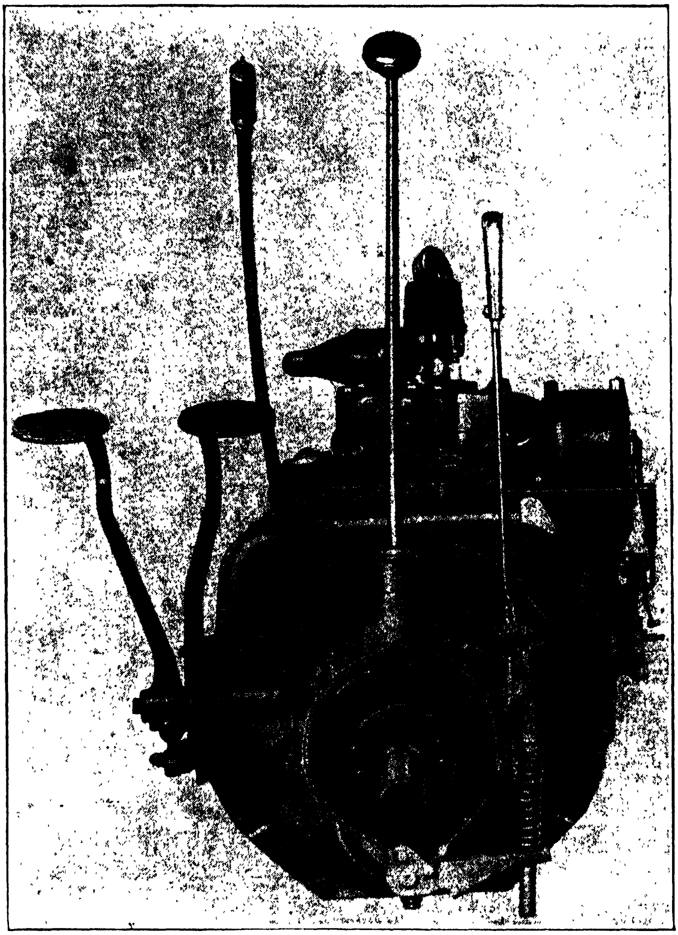


Fig. 69. Pontiac "Big Six" Transmission Brake for Hand Brake Use

The most important point of care then, with reference to the transmission brake, such as that illustrated in Fig. 69, is seeing that grease does not collect on the lining or drum. The next important feature is seeing that the brake lining is in good condition and does not wear unevenly. Perhaps the most important of all is to see that the brake adjustment is properly made so that the application of the hand lever will cause positive holding effort. Brakes such as this, when in good condition and properly adjusted, slide the rear wheels with very little effort on the part of the driver.

Servicing. When a job of brake work comes into the shop, the owner should be asked about the emergency brake and, if it is not satisfactory and safe, he should be urged to authorize servicing it. The usual service points are suggested below.

First check for grease or other dirt accumulation, and clean if necessary. Follow this inspection by the inspection of the brake lining clearance. This should not be less than .010 inch or .012 inch nor more than $\frac{1}{32}$ inch. Do not set up the brake lining clearance too close, since the drum will expand under heat and may cause binding or dragging.

If the lining is worn thin in spots or if it is saturated with grease, it should be replaced with new lining.

Check over the brake handle and the brake handle pawl or dog and the ratchet. It is of utmost importance that these be in good condition, because if they are not, the parked car may have the brakes jarred off by passing traffic and the car "run wild" if parked on a hill. Finally see that the springs used in connection with the brake are in good condition and that all parts are in proper alignment and properly lubricated so that the brake action is easy and at the same time positive and forceful.

"NOBACK" BRAKE

The Noback brake, Fig. 70, which is built into a number of automobiles at the rear of the transmission, is designed to prevent the automobile rolling backward when it is stopped on a grade. It is automatic in operation and works somewhat on the order of an over-running clutch. The Noback brake is operative at all times except when the car is being operated with the gear lever in reverse position, at which time it is automatically disengaged. Placing the gear lever in reverse position automatically releases the unit, and it remains inoperative until the car is again driven forward.

The Stutz-Blackhawk Noback mechanism is contained within a housing directly attached to the transmission housing, Fig. 71. This housing contains the locking hub, mounted on the splines at the rear of the internal drive gear, the locking roller, the locking shoe, and the push rod. The roller container which floats in the Noback housing is ground to conform to the outer diameter of the locking hub. This container is held away from the locking hub by the roller container spring mounted in the side of the housing. When the car is operated in a forward direction, this spring holds the roller container away from the locking hub approximately .003 to .005 inch. When the Noback is in the locking position, the locking roller is forced against the locking shoe by the tendency of the locking hub to rotate in the reverse direction, which overcomes the resistance of the roller container spring and forces the roller con-

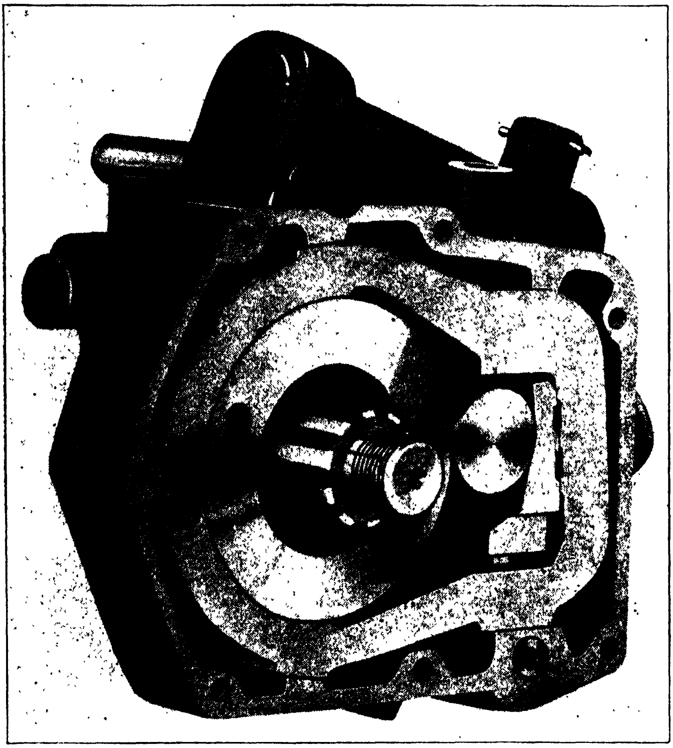


Fig. 70. Noback Unit Used on Stutz and Blackhawk Transmissions

tainer against the locking hub which acts as a very effective brake and prevents the car from rolling backward. Immediately the car is operated in a forward position, the friction between the locking hub and the locking roller lifts the roller on the locking shoe and permits the roller container spring to force the roller container away from the locking hub. The roller is carried in this position whenever the car is operated in a forward direction.

When the transmission is placed in the reverse position, the release shaft pinion rack is forced backward by the reverse shifting bar, which rotates the release shaft and lowers the release connecting shaft, which in turn rotates the release camshaft and permits the push rod to drop down against the inside of the roller container. This allows the locking roller to drop below center, making it impossible for the roller to exert a pressure against the locking shoe, which permits the locking hub to rotate freely in the reverse position.

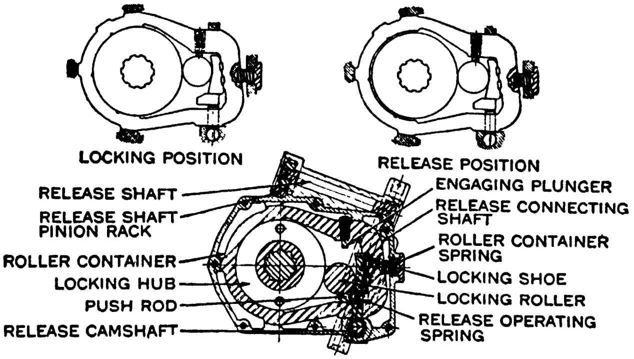
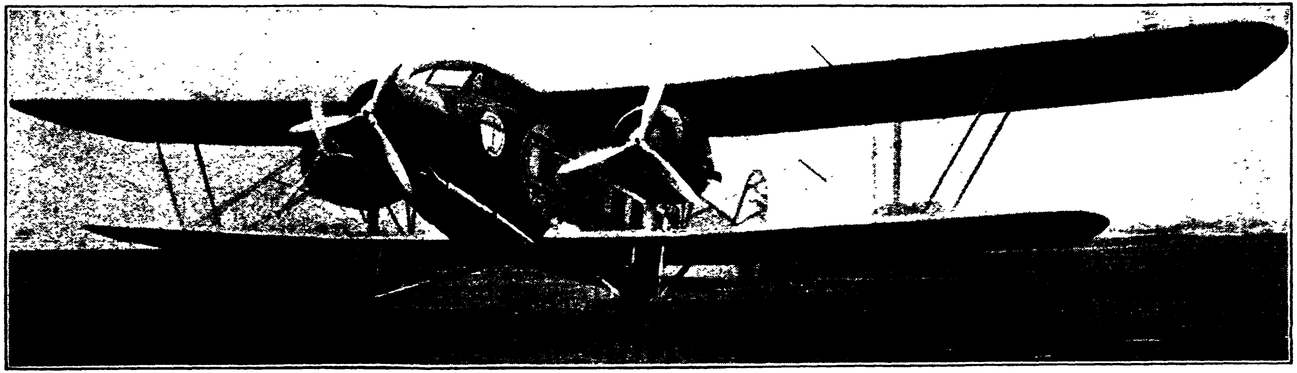


Fig. 71. Stutz-Blackhawk Noback Design

Immediately that the gear shift is removed from the reverse speed position, the roller does not return to the operating position. It is necessary that the car be moved forward approximately six inches, which will permit the locking hub to rotate the locking roller to the operating position. After the car has been moved forward approximately six inches, the gear shift lever may be placed in any speed position except reverse, and the Noback mechanism will prevent the car from rolling backward.



BOEING TRI-MOTORED PASSENGER TRANSPORT WITH THREE PRATT AND WHITNEY HORNETS EQUIPPED WITH N.A.C.A. COWLING

The plane which has accomodations for 18 passengers, 2 pilots, and a steward, has a top speed of 135 miles an hour. It was designed for use on a passenger route operating between Chicago and San Francisco and has a ceiling of 17,000 feet.

AVIATION ENGINES

PART I

Man's dreams of conquering the air have always hinged on the possibilities in the development of satisfactory power. During the World War certain pilots were in the habit of saying they could fly any kind of a "crate" if they had sufficient power. When the Wright Brothers were developing their first heavier-than-air flying machines, they were handicapped by lack of suitable power plants.

It is impossible herein to give a complete history of the airplane or even to give all the high points which have influenced the development of the aviation power plants, but there are certain fundamentals of design which have influenced the development of aviation engines and these requirements are discussed.

Aviation Engine Requirements. Power is the prime consideration. Reduction of weight is also fundamental and important. The two offset each other. If weight is increased, the power must be increased; and if weight is reduced in the power plant, it is likely that the power output will likewise have to be reduced. The ideal situation is arrived at when the power of the engine may be increased without the addition of weight. For many years it was felt that the ideal engine would be found if the weight could be kept down to not more than two pounds per horsepower. In fact, it took many years of experimentation and development work to secure a practical design which was less than three pounds per horsepower.

The Liberty airplane engines developed during the World War had a power rating of a bit better than 400 and weighed a bit over 900 pounds. The exact weights and power rating varied somewhat, but the usual statement with reference to the ratio between power and weight was $2\frac{1}{4}$ pounds per horsepower. The Liberty engines as well as most of the other engines built in America during the war years were water cooled. This meant that there was a certain addition of weight necessary in the way of cooling fluid, radiators, water pumps, and pump connections. There were many good engines built during this period and not a few of them have continued in service.

Maintaining the water-cooled system in perfect condition is a task difficult of accomplishment in the case of the airplane power plant. The extremes of temperature encountered cover a wide range, even in a given area, owing to the effect of altitude. Leaks occurring during flight are dangerous and impossible of repair. Forced landings may result. However, one advantage of the V-type airplane engine is the decreased head resistance which the jobs offer over the radial type engines, which are air cooled. Experiments which promise success are being conducted on the V-type air-cooled engines.

It was not until the advent of the successful air-cooled engine, that the power output was generally reduced to less than two pounds per horsepower. In America little was done with the air-cooled engine, such as shown in Fig. 1, until after the close of the war. In Europe engines of the rotary and fixed radial types had been developed and had given encouraging accounts of themselves. After the close of the war, the Lawrence Engine Company developed the first air-cooled engine which would stand the 50-hour test required of it by the United States Government.

Engine vibration is a vital consideration in aviation as well as in automobile use. Serious consequences may result from vibration of the engine, which shakes the airship apart or causes wiring or fuel and oil lines to fail. Building an aviation engine light and powerful and at the same time free from vibration is an art requiring the highest type of engineering design and manufacturing practice. At present there are a number of fixed radial aircraft engines of the type shown in Fig. 1 on the market which meet all requirements as specified and develop horsepower at the rate of one horsepower for each $1\frac{1}{2}$ to $1\frac{3}{4}$ pounds of engine weight.

Fixed Radial Airplane Engines. The fixed radial airplane engines are all of the air-cooled type. In appearance they are quite similar to the rotary engine of the type of the LeRhone, which was popular during the war. The difference is in the fact that the crankshaft of the rotary engine is stationary and the engine cylinder and crankshaft assembly rotates around it, while in the radial type the cylinders are fixed and the crankshaft revolves as in any automobile engine. There are a number of serious objections to the rotary type of the air-cooled engine. These have to do with oil consumption, manifolding, vibration, and similar difficulties—

difficulties that are so great that this type of engine is now considered obsolete.

Curtiss "OX-5" Engine. The Curtiss eight-cylinder V-type engine was turned out in considerable numbers during the war and since that time has continued to be a real aid to the development of aviation. It is a light-weight engine, which might be termed as belonging to the "flivver" class of aviation engines. As such, it has been used by many schools in the training of pilots. It is used by some manufacturers of light planes as power units for new planes. It is economical in flight. It is a water-cooled engine and the smallest

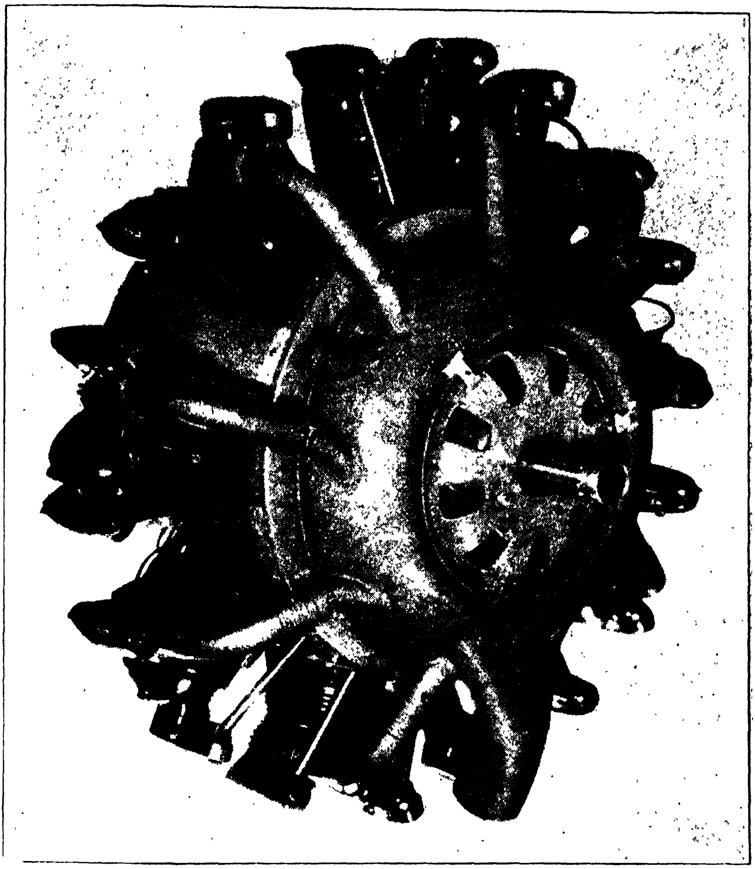


Fig. 1. Three-Quarter Front View of Wright "R-1750" Wright Cyclone Engine

of the many water-cooled power plants turned out by the Curtiss Company.

Since the war, the Curtiss Company have made a great deal of progress in the manufacture of airplane engines. The 12-cylinder Curtiss Model "D-12" engine, Fig. 2, is used in both the army and navy planes and are of the high and low compression types. It is of the V-type with the cylinders set at an angle of 60°, which is the usual setting for a 12-cylinder engine. It has a bore and stroke of 4½ by 6 inches and develops 400 brake horsepower at 2,000 revolutions per minute at sea level. The maximum number of revolutions per minute is 2,300, but it is operated most economically at 1,850. The pistons are of aluminum with a piston displacement of 95.4 cubic inches.

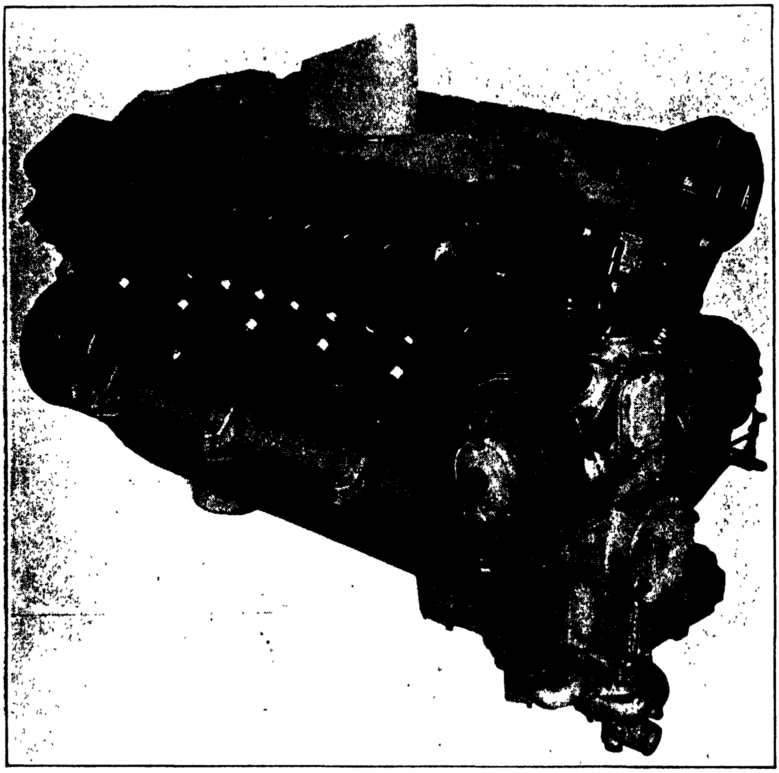


Fig. 2. Curtiss 12-Cylinder Airplane Engine
Courtesy of Curtiss Airplane Engine Company

The engine fires in the following order: 1L—6R—5L—2R—3L—4R—6L—1R—2L—5R—4L—3R. The cylinders are water cooled, using a centrifugal pump for circulating the water throughout the cooling system. Lubrication is of the force-feed type, a gear pump being used for the circulation of the oil. The weight of this engine with water and accessories installed is 724 pounds, giving 1 horsepower for about 1.8 pounds of weight, showing a remarkable development in design as well as in the choice of materials for the greatest service and lightness. Ignition is by the high-tension Model "SS"-12 Splitdorf magneto, while the carburetor is of the Stromberg-Duplex type, Model "NA-Y5."

Liberty V-Type Engine. The Liberty engine was developed purely and simply for war work by American engineers, along American lines, and specifically for American methods of production. It was not strictly an original design, many major elements and groups of elements being adopted bodily from existing American engines, notably the Packard aviation engine and the Hall-Scott. This made possible quick production, for these two companies started immediate manufacture of these adopted parts and in addition started at once to instruct subcontractors on these same parts. All this was done practically without waiting for the design to be completed, tried out, and improved as a result of the tryouts.

In Fig. 3 is shown an end view of a Liberty engine ready for test at the Bureau of Standards. Fig. 4 gives a cross-section of the form using a cast cylinder, showing incidentally the crankshaft and connecting rods, piston and cylinder construction, valve location and operation, and water-jacketed inlet manifold. This engine has a bore of 5 inches and a stroke of 7 inches, and the cylinders are set 45 degrees apart—22½ degrees each side of the vertical.

The angle of the cylinders gives an uneven firing impulse. The left-hand cylinders fire and move the crankshaft 45 degrees and the right-hand cylinders fire and move the crankshaft 75 degrees. The setting of the cylinders gives a more compact engine and reduces the head resistance. This uneven firing impulse gives a good deal of vibration at low speeds, but at the operating speed of the engine this vibration is not felt at all.

Development of the Air-Cooled Fixed Radial Engine. During the war period Charles L. Lawrence had been perfecting the air-cooled aircraft engine. Following several years of previous experience in the design of automobile and aircraft engines, in 1919 he started the development of air-cooled engines of small power. His early experiments led him to believe that larger engines of similar type could be successfully constructed. He was encouraged in his research by the United States Army and Navy. These departments felt sure that the development of this engine held such promise that the Navy gave the Lawrence Company a production contract for fifty.

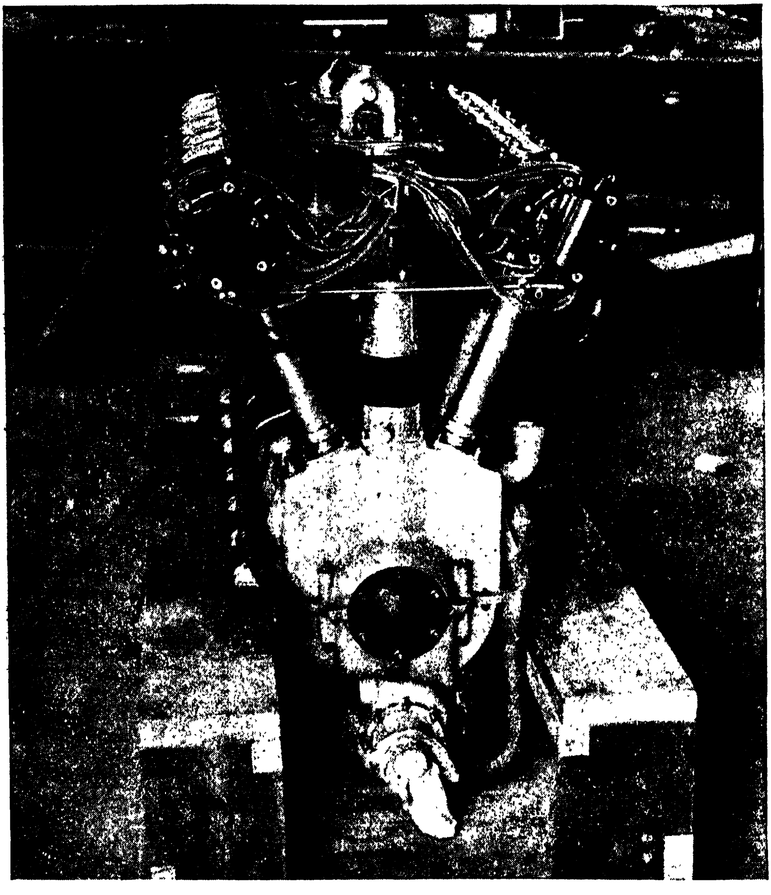


Fig. 3. End View of Liberty Motor at National Bureau of Standards, Washington, D.C.

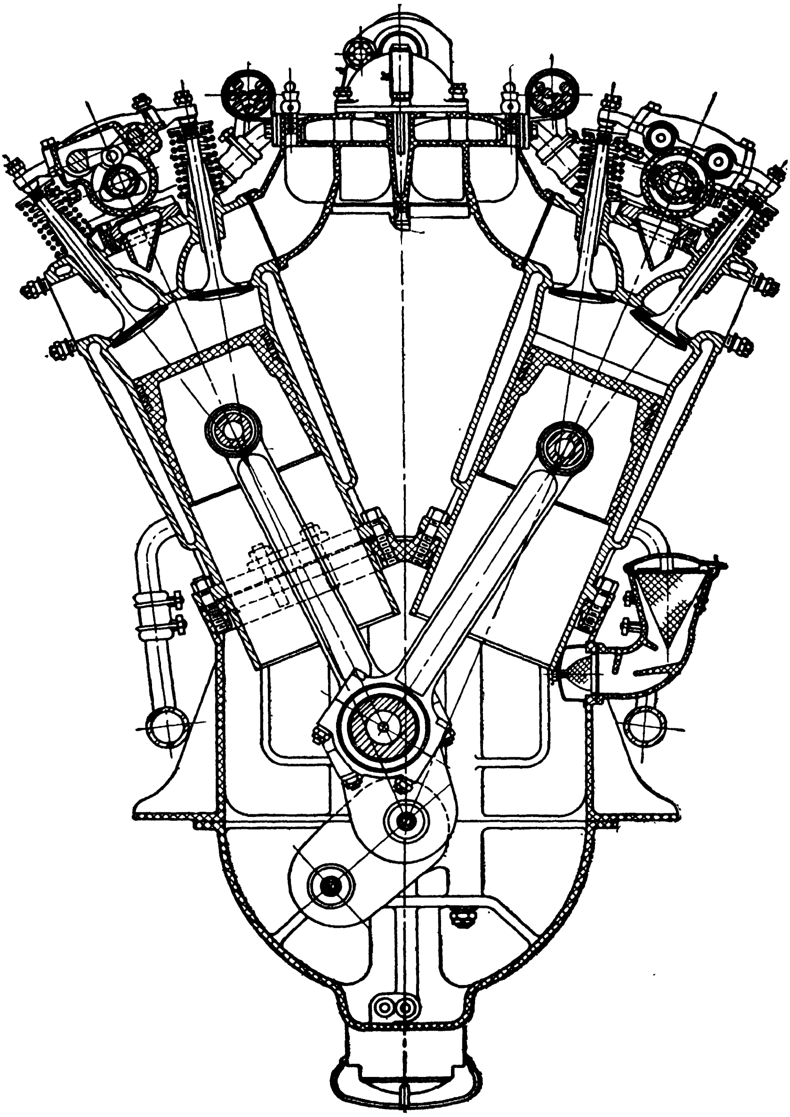


Fig. 4. Cross Section of Liberty Motor with Cast Cylinders

This second engine, designed and constructed for the United States Navy, was the forerunner of the series of Wright "Whirlwind" engines, having a bore of 4½ inches and a stroke of 5½ inches, and rated at 200 hp. at 1,800 r.p.m. Since that time a number of successive models have been produced without alteration in the basic design. Each model has been produced in quantity for the United States Navy before being released for commercial sale. In this way commercial aviation in the United States has had the benefit of time-tested engines of a design already approved and tried by the United States Navy.

The Wright "Whirlwind" is the result of intensive development on one type of engine without alteration in bore and stroke and without changing any basic feature of the original design. The development contract under which this series of models began was dated February 28, 1920. Since that time many successive models have been developed. This service testing in the hands of the United States Navy and many commercial interests has resulted in a wealth of practical experience and technical data, which has formed the groundwork for further improvement in detailed design. These improvements have first been developed and tested in the laboratory through extensive dynamometer trials and later supplemented by flight tests where average service conditions were simulated.

Commercial air transport as a necessary factor in speeding up modern business is everywhere accepted. The great need is to bring the cost of the airplane and of air transport within the means of the individual in his routine activities of everyday life; to place at the disposal of the operator and private owner widespread mechanical service facilities at convenient locations and at moderate cost.

The rapid growth of the commercial aircraft industry of recent years has been largely based upon the development and commercial production of the fixed radial air-cooled engines, because these engines have in all classes of service in this country and abroad demonstrated a degree of efficiency, high performance, and rugged dependability that has set the industry ahead by great strides.

THE THREE WRIGHT "WHIRLWINDS"

Wright engineers have developed a series of three engines—ranging in power from 150 h.p. in the 5-cylinder model, through 225 h.p. in the 7-cylinder model, to 300 hp. in the 9-cylinder model—so constructed that almost all the component parts are directly interchangeable, thus greatly increasing the volume of production and reducing costs. The fact that 94 per cent of the parts of these three engines are directly interchangeable greatly simplifies the problem of making readily available to the airplane users a wide distribution of standardized service equipment in the operating field. The same repair and maintenance parts that are required by the private ower of a small plane powered with a 5-cylinder 150 hp. engine are directly applicable to the operator of the larger cabin plane using the 7-cylinder 225 hp. engine, and to the operator of the large three-motored passenger transport plane using the 300 hp. 9-cylinder engine. The mechanic who is familiar with one model is familiar with all, for all engines are practically identical except for the number of cylinders and their supporting crank cases.

Side by side with the development of this series of engines in the smaller power class, there has been developed the still larger and more powerful Wright Cyclone, a 525 hp. 9-cylinder engine.

The three Wright "Whirlwinds" having five, seven, and nine cylinders, respectively, are radial engines with stationary cylinder and rotating crankshafts. They are of the four-cycle type, working on the same principle as the usual automobile engine, but with only one crank throw for the entire set of pistons, instead of a separate throw for each piston.

It is impracticable to attach connecting rods from all of the cylinders to a single-throw crankshaft. The connecting rods from the piston in the vertical cylinder is the only rod attached directly to the crankshaft. It is known as the master rod. The remaining connecting rods, Fig. 5, are attached to the big end of the master rod by link pins, all connecting rods and pistons thus working together as the crankshaft revolves.

All accessories on the engine are at the rear, including the valve-actuating push rods. This arrangement, Fig. 6, reduces the head resistance of the engine when in flight and permits of a very neat and simple cowling design. The accessories, such as magnetos, are also protected against rain, snow, ice, dust, etc., by this design. It has been proved by actual flight tests that an appreciable increase in airplane speeds is obtainable by this reduction in head resistance.

Each engine is provided with a front exhaust manifold of the collector ring type, Fig. 7, and with a nose cowling with shutters operated from the pilot's seat. The movable shutters permit the flow of air around the crank case and cylinders to be regulated so as to give the maximum engine efficiency under varying climatic conditions and atmospheric temperatures. The provision of the manifold and cowling also relieves the airplane manufacturer of many installation difficulties.

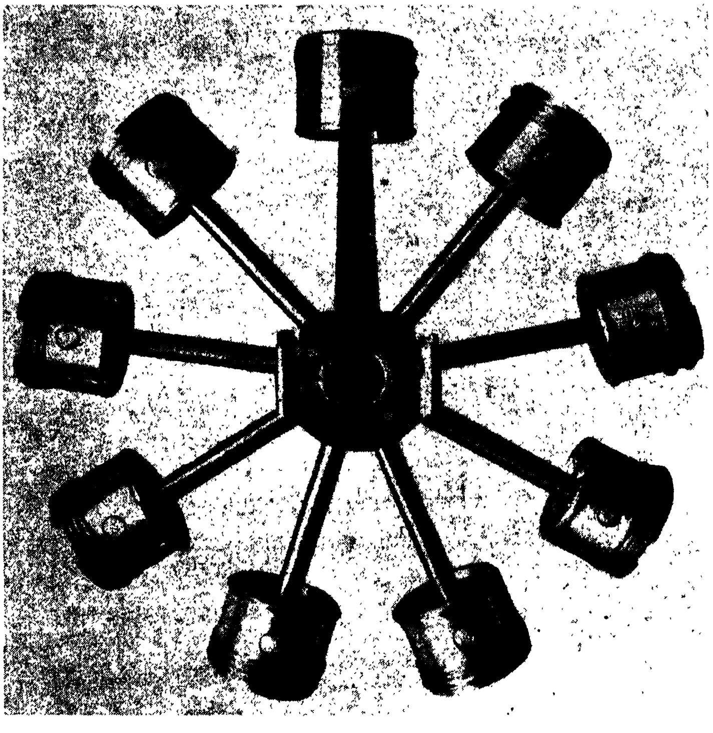


Fig. 5. Master and Link Piston-Rod Assembly

Crank Case. The crank-case assembly is composed of four major castings of aluminum alloy. The cam follower ring carrying the tappet guides is cast integral with the main section of this crank case, thus giving rigid and absolutely accurate support and perfect lubrication to the tappets and eliminating a number of detail parts, with a consequent saving in weight and increased reliability.

The rear section carries all accessory drives, comprising those for magnetos, oil and fuel pumps, generator, and rotary induction system. Provision is made for the easy installation of suitable generator and starter. The first "R-540" engines were built without generator drives. The whole crank-case unit is exceptionally strong, compact, and light in weight.

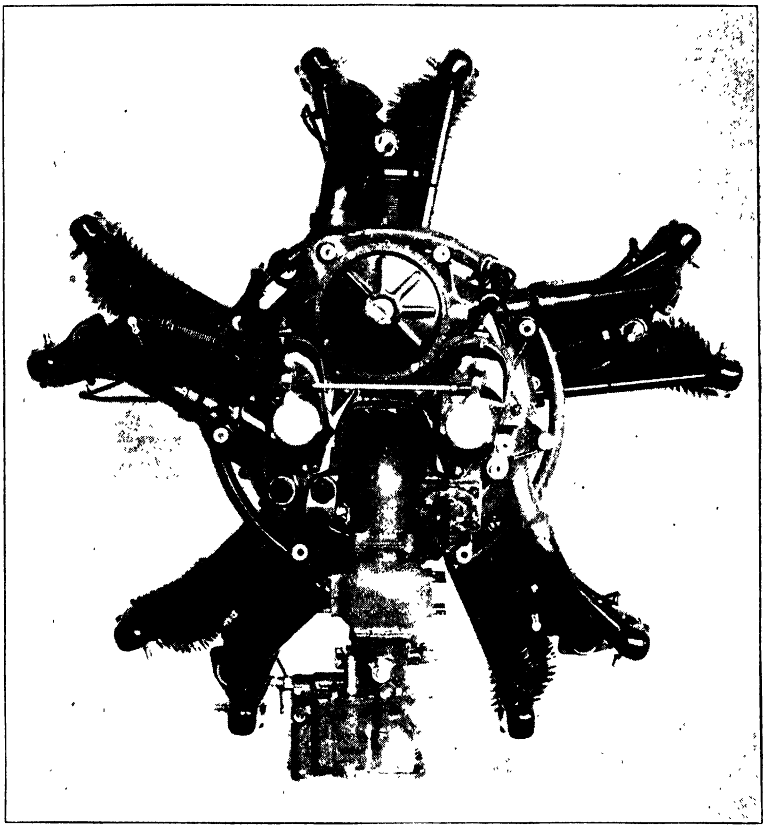


Fig. 6. Rear View of Wright 5-Cylinder "J-6" 150-Horsepower Engine

Crankshaft. The crankshaft, Fig. 8, is of the single-throw two-piece type, made from alloy steel forgings and counterbalanced to prevent vibration. It is drilled for oil passages, giving positive pressure lubrication to the bearing surfaces.

Bearings. All bearings are of ample size, generously lubricated, and of either a plain or ball-race type as required for use.

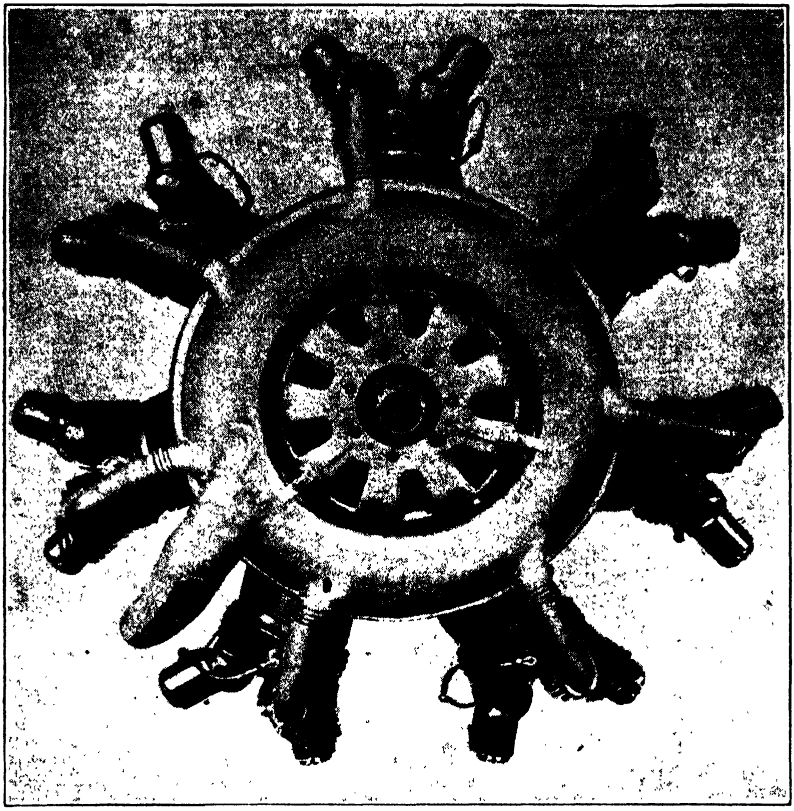


Fig. 7. Wright "J-6" 7-Cylinder 225-Horsepower Engine

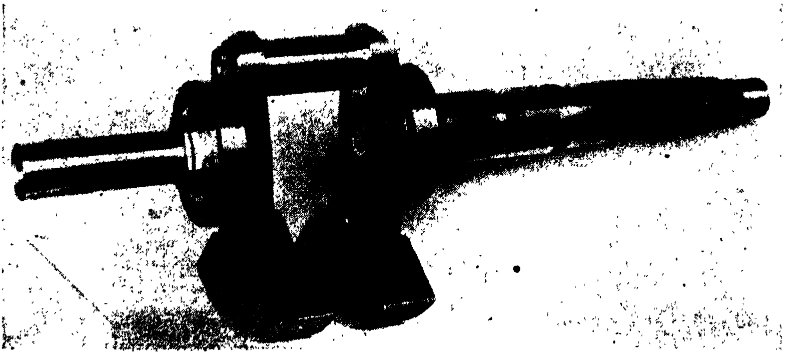


Fig. 8. Crankshaft with Front and Rear Bearings

Connecting Rods. The connecting rods are of forged alloy steel and consist of a one-piece master rod, see Fig. 5, and articulated rods one for each cylinder. The wrist-pin and knuckle-pin bushings are of bronze pressed into the articulated rods. The crank-pin bearing is of anti-friction metal, steel backed, pressed, and doweled into the big end of the master rod.

Cylinders. The cylinders are composed of a steel barrel, Fig. 9, over which an aluminum alloy head is screwed and shrunk. Each cylinder is attached to the crank case by eight steel studs passing through the cylinder flange and has cooling fins so arranged as to give efficient working temperatures under all conditions. The intake ports are at the rear of the cylinders, as in all Wright engines, with the exhaust ports on the forward side to obtain the most effective cooling. The excellence of this design is well demonstrated by the remarkably low fuel consumption.

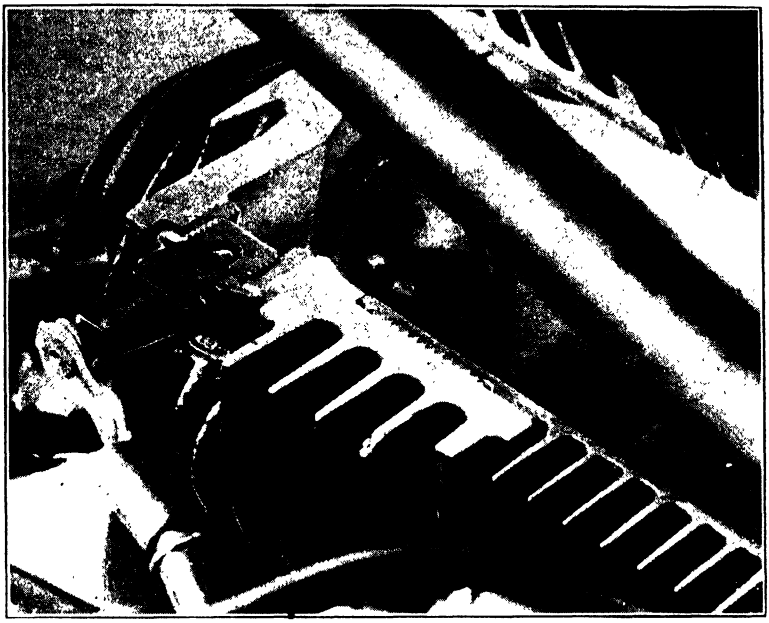


Fig. 9. Showing Construction of Cylinder Head

Pistons. The pistons, as shown in Fig. 5, are of aluminum alloy, crossribbed on the under side of the head and fitted with full-floating hollow pins held in place by expanding spring wire locks. The ends of the pins are thus positively prevented from wearing the cylinder walls. Piston pins and cylinder walls are lubricated by oil spray from the crank and knuckle-pin bearings. The external surface of the piston head is slightly concave, which in conjunction with the internal shape of the cylinder head results in an almost ideal spherical combustion chamber.

Valve Gear. Hardened steel cam followers, Fig. 10, operate through hardened steel rollers running on the cam ring; push rods of hollow steel tubing fitted with casehardened steel ball ends actuate the forged steel rocker arms. The rocker arms, Fig. 11, are carried on ball bearings, lubricated by the Alemite or Zerk pressure system, and have provisions for the adjustments necessary for correct valve clearances. The whole valve mechanism, including push rods, is completely enclosed as a protection against dust, salt spray, etc., the rocker shafts being mounted in a housing cast integrally with the cylinder head.

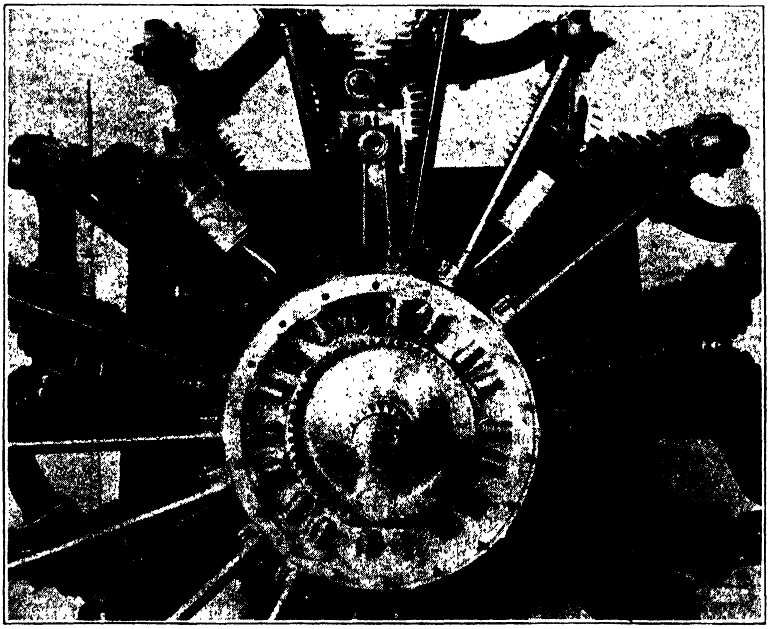


Fig. 10. Front View of Master Rod in Top Dead Center Ready for Power Stroke

Valves. Tulip shaped valves, see Fig. 11, of ample area are used with a solid-stem inlet valve and hollow-stem exhaust valve. The valve springs are helical and made from special heat-treated spring-steel wire; three springs—outer, intermediate, and inner—are fitted concentrically to each valve to insure complete reliability in flight. One spring will operate the valve in emergency.

Lubrication. Lubrication is provided by a pressure pump, which carries oil into the rear end of the hollow crankshaft from which point it is distributed to all bearings under pressure. The excess oil running through to the front end of the crankshaft is collected there and returned to the rear of the crank case by means of one suction pump. A second suction pump carries oil from the rear section of the crank case to the oil tank, passing through an oil strainer where any foreign matter picked up in the engine is strained out. The only two parts of the engine not lubricated under pressure are the cylinder walls and the wrist pins. These are lubricated by a limited amount of oil which is permitted to fly out of the crankshaft

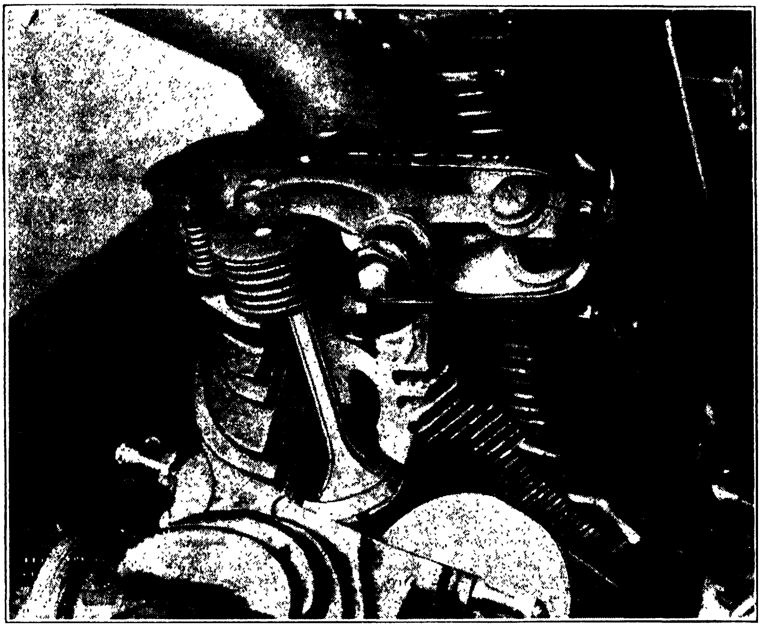


Fig. 11. Valve and Valve Actuating Mechanism on Cylinder Head

in the form of a spray and within the crank case. The oil used for cylinder lubrication is that burned by the engine. The remaining oil is used over and over through the complete circulation system, made up of the oil storage tank and the engine itself.

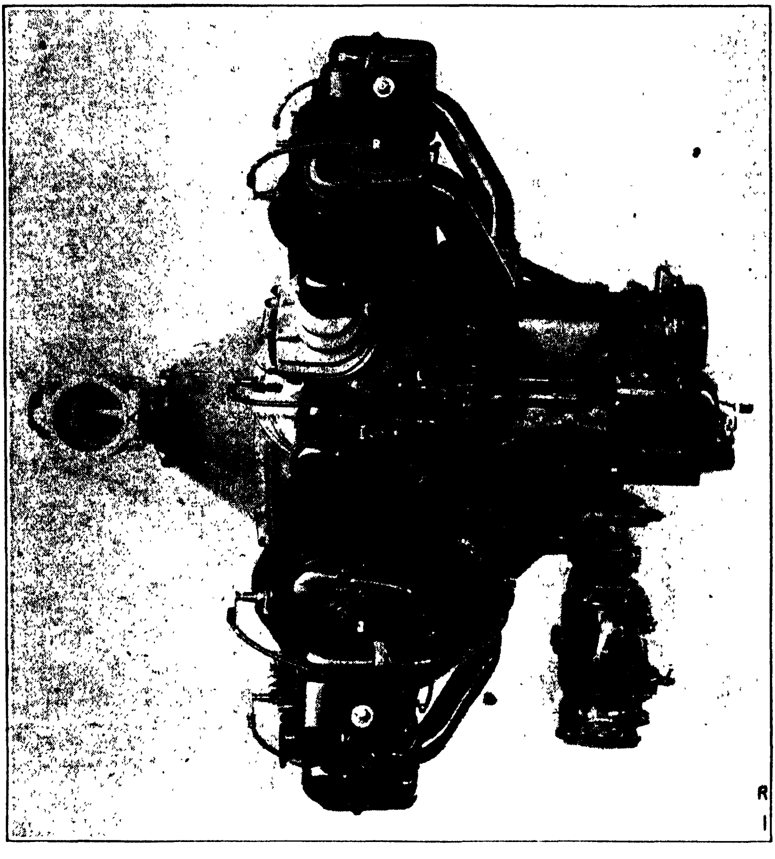


Fig. 12. Full Side View of Wright "R-975" "J-6" Whirlwind Series 300-Horsepower Engine

The lubrication system is carefully designed so as to eliminate entirely all external oil pipes, as these have been found liable to leakage and have proved unsatisfactory in service, due to excessive chilling of the oil in cold weather.

Ignition. Two Scintilla magnetos, Figs. 12 and 13, mounted behind the engine and operating independently provide ignition to two separate spark plugs in each cylinder. The magnetos are normally in simultaneous use, but the engine will operate in an emergency on one magneto with a slight loss of revolutions per minute.

Firing Order. With this construction the entire connecting rod and crankshaft system revolves as a unit and the explosive impulses occur progressively in the direction of propeller rotation on alternate cylinders. The firing order is therefore 1—3—5—7—9—2—4—6—8. The engine being of the 4-stroke cycle type, there are nine explosions for each two revolutions of the crankshaft.

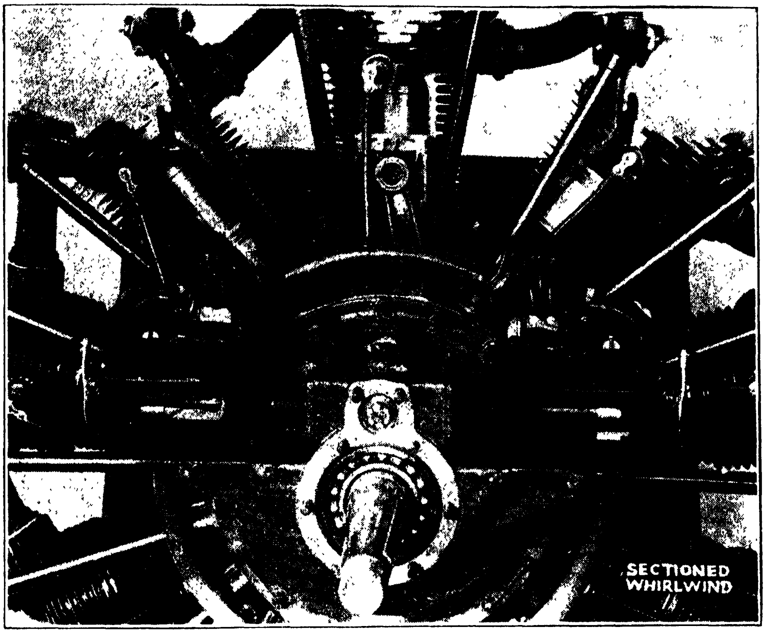


Fig. 13. Front View of Crank Case with Front Cover Removed

Carburetion. The fuel mixture is supplied by a special Stromberg carburetor of the single-barrel type mounted on the rear section of the crank case. The mixture passes from the carburetor to the diffuser chamber of the crank case and is evenly distributed to all cylinders by the rotary impellor mounted in this diffuser chamber.

The positive control of the distribution of the mixture obtained by the Wright design of the rotary induction system gives a perfectly smooth running engine. This is of special value for the small engines since it eliminates the vibration caused by unequal distribution of combustible mixture.

A "hot spot" is provided above the carburetor, which thoroughly vaporizes the fuel mixture, this feature serving to insure the smooth running of the engine on various types of gasoline. The "hot spot" temperature can be regulated from the pilot's seat in order to obtain maximum efficiency and fuel economy under all flying conditions.

In addition, provision is made for obtaining at all times a supply of clean air to the carburetor. All fuel consumption and power guarantees are based on the use of Domestic Aviation gasoline with no admixture of anti-knock compounds.

Installation of Controls. The same type and diameter of mounting ring can be used for all three Whirlwind engines. All controls are placed at the rear of the engine, thus simplifying installation in the airplane.

Air Cooling. The air-cooling system really means that the heat of combustion is transferred directly from the cylinder to the atmosphere. This is accomplished by means of fins surrounding the cylinder and cylinder head. This method eliminates the use of cooling water and the fragile radiator common to automobiles and the older type of aviation engines. It results in large decrease in weight and great increase in engine reliability.

Durability of Engine. Wright "Whirlwind" engines are averaging in excess of 250 hours between overhauls. Expressed in automobile terms, this means that the engine travels approximately 25,000 miles before requiring attention. The ultimate life of the engine is approximately 2,000 hours, which, expressed in automobile terms, means an ultimate life of approximately 200,000 miles. This figure greatly exceeds the life of the average automobile now being manufactured.

Economy. The fuel consumption of the Wright "Whirlwind" engine is the lowest of any production aviation engine now available. Colonel Lindbergh made approximately 10 miles per gallon in his flight to Paris and during his trip he did not make any special effort to conserve gasoline. Pilots Chamberlain and Acosta, during their endurance flight of 51 hours, made a slightly better average of gasoline consumption per mile flown.

Power Curves. The power curve diagram, Fig. 14, indicates the power output and fuel consumption of the 9-cylinder engine at various speeds. The "Full Throttle Power" curve shows the average

ENGINE SPECIFICATIONS

Model "J-6" Series

Type	R-540 Air-cooled four-cycle fixed radial	R-760 Air-cooled four-cycle fixed radial	R-975 Air-cooled four-cycle fixed radial
No. of cylinders	5	7	9
Bore	5 inches	5 inches	5 inches
Stroke	$5\frac{1}{2}$ inches	$5\frac{1}{2}$ inches	$5\frac{1}{2}$ inches
Displacement	540 cu.in	756 cu.in.	975 cu.in.
Compression ratio	5:1	5:1	5:1
Guaranteed hp. (sea level)	150 @ 1800 r.p.m.	225 @ 2000 r.p.m.	300 @ 2000 r.p.m.
Fuel consumption (max.)	.55 lb. hp.-hr.	.55 lb. hp.-hr.	.55 lb. hp.-hr.
Oil consumption (max.)	.035 lb. hp.-hr.	.035 lb. hp.-hr.	035 lb. hp.-hr.
Length overall (no starter)	$40\frac{5}{8}$ inches	$40\frac{23}{32}$ inches	$41\frac{7}{16}$ inches
Mounting flange to propeller hub	$28\frac{29}{32}$ inches	$28\frac{29}{32}$ inches	$28\frac{29}{32}$ inches
Diameter overall	45 inches	45 inches	45 inches
Weight (dry)	370 lbs.	425 lbs.	485 lbs.

maximum power output at the engine speeds tabulated across the bottom of the diagram. Individual engines may vary from 2 to 3 per cent above or below the power output shown. The "Propeller Load" curve is based on the rated speed of each type of engine, showing the power output obtained at a given engine speed with the engine fitted with a propeller which will permit the engine to reach the rated revolutions per minute at full throttle.

For example, the rated speed of the "Whirlwind Nine" is 2000 r.p.m. The "Propeller Load" curve for this engine shows a power output of 315 hp. at this speed. At 1800 r.p.m., the output is 229 hp., and so on through the range of the curve. If the full throttle speed is above or below 2000 r.p.m., owing to the type of propeller fitted, the propeller load curves will start at that point on the power curve corresponding to the maximum r.p.m. and will be similar in form to the propeller load curve drawn from 2000 r.p.m.

From the fuel consumption curves it will be seen that for all of the full rich positions of the carburetor mixture control, the specific fuel consumption in pounds per brake horsepower hour decreases from .600 at 1600 r.p.m. to .570 at 2300 r.p.m. on the full throttle power curve. With the mixture control adjustment utilized to increase the proportion of air to fuel in the carburetor to the maximum point at which the engine still loses no r.p.m., the fuel consumption is as indicated on the "Best Setting" curve for full throttle power. The fuel burned ranges from .530 pound per brake horsepower hour at 1600 revolutions per minute to .500 pound at 2300 revolutions per minute.

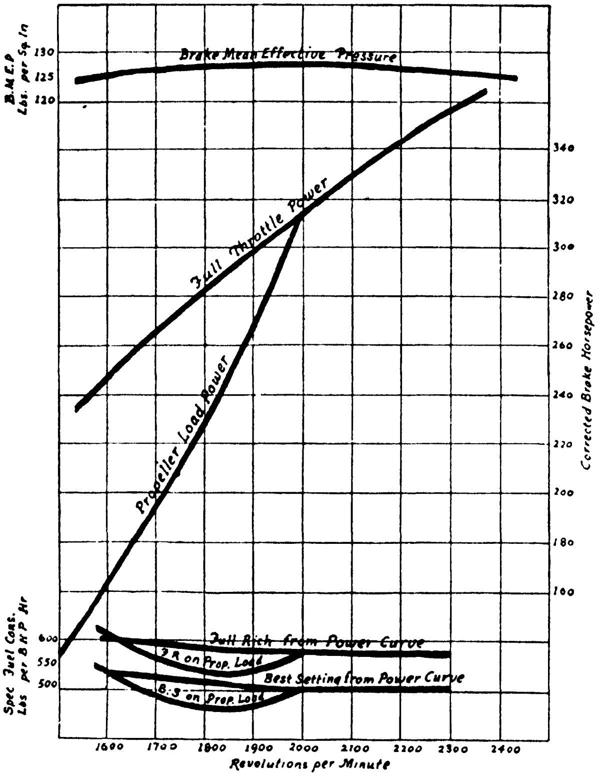


Fig. 14. Wright Whirlwind Model "R-975" 9-Cylinder Aircraft Engine
Power curves at full throttle and on propeller load; fuel consumption at full rich and best setting; compression ratio 5:1 to 1; aviation gasoline.

These two curves also show how the fuel consumption can be varied at any fixed revolutions per minute by using the mixture control. For example, at 1800 revolutions per minute the fuel used varies from .518 pound to .586 pound, according to the setting of the mixture control. The "Propeller Load" fuel curves indicate a similar variation of fuel consumption corresponding to changes in revolutions per minute and the position of the mixture control valve on the carburetor.

The upper "Propeller Load" shows the fuel burned at various revolutions per minute with a "full rich" mixture; the lower "Propeller Load" curve demonstrates clearly the result of using the mixture control.

It should be noted that considerably lower fuel consumption than that indicated on the curves can be obtained in actual flight by intelligent use of the mixture control. The method of procedure is to set the mixture control at the "full rich" position and the throttle control at the point where the engine speed is from 25 to 30 revolutions per minute above that required; the mixture control is then opened out to give the carburetor additional air until the engine revolutions per minute have decreased to the required speed. The engine is then operating on the most economical mixture, consistent with smooth running.

Accessories. The accessories recommended by the Wright Company for use on Wright engines have been exhaustively tested under widely varying conditions of practical operation. These accessories only should be used, as the satisfactory performance of the engine is materially affected by the use of unsuitable items of equipment. This applies particularly to air-heaters, fuel pumps, propeller hubs, generators, starters, and spark plugs; in the case of the tachometers, oil pressure gauges, and oil thermometers, any instrument approved for use by the U.S. Army and U.S. Navy is suitable for the Wright engines.

Air Heater. The later "Whirlwind" engines are fitted with an air heating device as standard equipment; this results in better fuel distribution and economy as well as preventing the formation of ice in the carburetors.

Hot Spot. All the later engines also have incorporated in their construction a "hot-spot" in order to improve carburetion and operating efficiency, in addition to insuring smooth running of the engine when gasolines of varying types are used.

Exhaust Manifold. A front collector-ring type exhaust manifold is standard equipment on the late type engines; the provisions of this item represents a considerable advantage to purchasers of Wright engines as it obviates entirely the expense and difficulty involved in manufacturing and fitting a manifold subsequent to the purchase of the engine.

Nose Cowling. The variable-shutter design of nose-cowling supplied with all engines has proved most satisfactory in enabling the pilot to obtain the maximum efficiency from the engine when in flight. This shutter is controlled from the pilot's seat, thus allowing the crank case and cylinder temperatures to be regulated to the desired degree under changing climatic and atmospheric conditions.

Fuel Pumps. In the case of airplanes which do not permit a gravity feed with at least a 20-inch head of gasoline to the carburetor, it is necessary to attach a fuel pump to the engine. The Wright pump is engine driven and has an adjustable pressure device which controls the quantity of fuel delivered to the carburetor.

Tachometers. Two tachometer drive connections are fitted to the engine. These take the U.S. Army Air Corps standard tachometer connections from which the tachometer cable can be carried to the instrument board or other location in the airplane.

Oil Thermometer. A connection for the oil thermometer pipe is provided in the oil strainer located outside the engine at some convenient point in the airplane. The oil temperature reading obtained is that of the oil coming from the engine and should not be allowed to exceed 1800 degrees Fahrenheit.

Starters. Any type of starter with a standard mounting flange can be used. Starters of the geared hand type, with booster magneto, or of the concentric inertia type, either hand or electrically driven, can be fitted. All starters are equipped with torque-overloaded releases to prevent abnormal stresses in the mechanism should the engine back-fire while starting.

Propeller and Hubs. The crankshafts of all the new "Whirlwind" engines are splined to take propeller hubs of the splined type. This obviates the need for lapping in the hub and insures a perfect fit with the minimum possibility of vibration due to any slight inaccuracy in the work of fitting the hub.

"WHIRLWIND" ENGINE OPERATION

Valve Action. Fig. 10 shows a front view of the engine with the master rod in the top dead center position ready for the power stroke. The front crank-case section has been removed, leaving exposed all the moving parts in the crank-case intermediate section. A clear view is obtained of the roller cam followers, which slide in forged steel guides in the intermediate section of the crank case. The exhaust cams are in front and the intake cams behind. The cam turns in the opposite direction to the crankshaft and at one-eighth crankshaft speed. In Fig. 10 the cam is turning clockwise and it will be noted that the relatively slow rotational speed is made possible by the use of four lobed cams.

Magneto Drive. Fig. 13 shows a front view of the engine with the crank-case front cover removed. This cover serves as a thrust plate to take the propeller thrust, holding the thrust bearing in place. The thrust bearing is a deep-grooved type radial ball bearing. Just above the thrust bearing is the nut which locks the cam and magneto timing device. Separate timing is also provided for each magneto in the adjustable variable type coupling, which is clearly shown. The cylinders are numbered in an anticlockwise direction, starting with No. 1 at the top. No. 2 piston is near bottom dead center, and No. 9 is fairly near top dead center. Note that the exhaust valve in No. 2 cylinder is wide open. In the top of the crank-case front section can be seen a part of the spur gear which is driven by the cam drive gear on the crankshaft. This spur gear is mounted on a shaft together with the pinion which drives the cam and the bevel gear which drives both magnetos. It is not keyed to the shaft but drives through a serrated dog timing mechanism.

Magneto Construction. Fig. 15 shows a close-up view of the Scintilla nine-cylinder magneto cut away to show the interior parts. At the left is the contact breaker assembly, showing the method of rotating the entire assembly for advance and retard adjustment. At the top inside of the magneto on the left is a fixed coil which is energized by the magnetic clutch passing through the laminated iron pole pieces from the rotating permanent magnet shown below. The permanent magnet is on the same shaft with the contact-breaker cam and with the small gear which drives the distributor on the other end of the magneto. On the distributor shaft, ahead of the coil, can be seen the safety spark gap. Note also the easily removable distributor block, held by a spring bar and a safety pin type of lock.

Rod Assembly. Fig. 16 is a view of both the crank-case front section and the intermediate section removed. The push rod, push-

Fig. 15. Close-Up View of Scintilla 9-Cylinder Magneto Cut Away to Show Interior

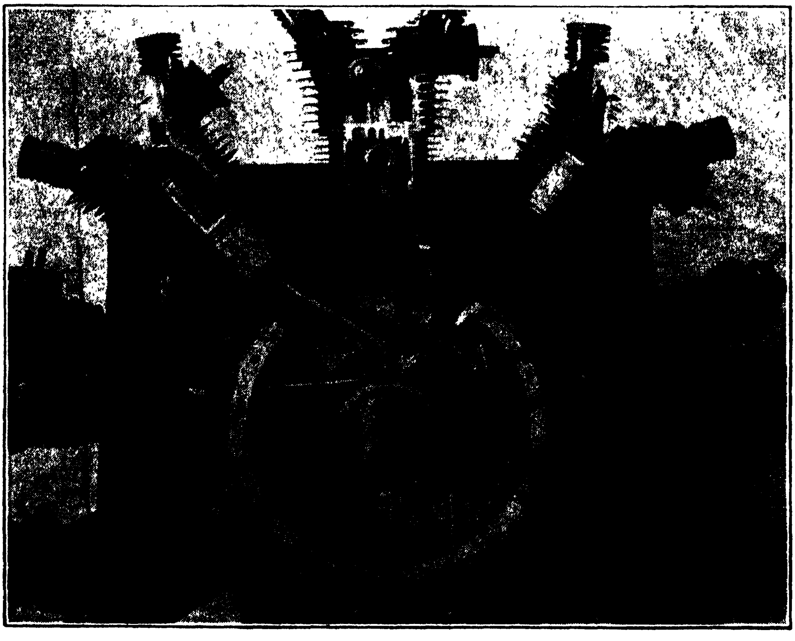


Fig. 16. Front Section of Crank Case and Intermediate Section Removed

rod housing, and valve rockers with their housings are also absent. The crankshaft with its front main bearing and its counterweight and the method of attachment of the master connecting rod and the articulated connecting rods are clearly shown. No. 9 piston is at top dead center. No. 1 piston in the vertical master-rod cylinder is approaching top dead center. Note the location of the main crankcase breathers on either side of and behind No. 1 cylinder. All the knuckle pins which connect the articulating rods to the master connecting rod are drilled for lubrication of the bushing in the articulated rod. The knuckle pin must therefore be locked against rotation to prevent shutting off the oil supply. Two of these locks are clearly shown in the illustration. They are like small square nuts with the inside edge beveled, fitted against a beveled flat spot on the edge of the knuckle pin. They are held tightly against the face of the master rod and against the beveled sides of two adjacent knuckle pins by small hexagon head cap screws, which in turn are locked against rotation by special brass safety wires. Note also the safety wiring on the four master-rod bolts which hold together the two halves of the master rod.

Crankshaft and Rod Hook-Up. Fig. 17 shows the crankshaft and connecting-rod assembly as in Fig. 16, but with all connecting rods in a different position. No. 1 piston is at bottom dead center. No. 9 is near bottom dead center and about to rise. The normal assembly of the piston and piston head, with aluminum guide plates at the end of each pin, is shown in No. 2 cylinder. In No. 1 cylinder the guide plug has been removed to expose the end of the piston pin and its interior. The guide plug in the far end of the piston pin can be seen.

Valve Mechanism. Fig. 11 is a very good close-up of the valve and valve-actuating mechanism on the cylinder head. On the right hand or forward end of the valve rocker is shown the large valve adjusting screw, which is hollow and cup-shaped on its lower side. Inside of it is fitted a small carefully ground piece of ball-bearing steel which takes the thrust and the wear of the ball end of the push rod. The graduations around the valve adjusting screw indicate a movement of the screw corresponding to .005-inch change in the valve clearance. The screw is locked against rotations by a clamp screw running through the forward end of the boss on the valve rocker. The hole for this clamp screw is clearly shown. Because of the fact that the push rods are at an angle to the central axis of the cylinder, hard steel thrust washers are placed on the valve rocker fulcrum pin on either side of the rocker. These thrust washers and the bushing in the rocker are lubricated by the Alemite fitting shown. Side thrust on the valve stem itself in the guide is reduced by the use of the roller on the end of the valve rocker.

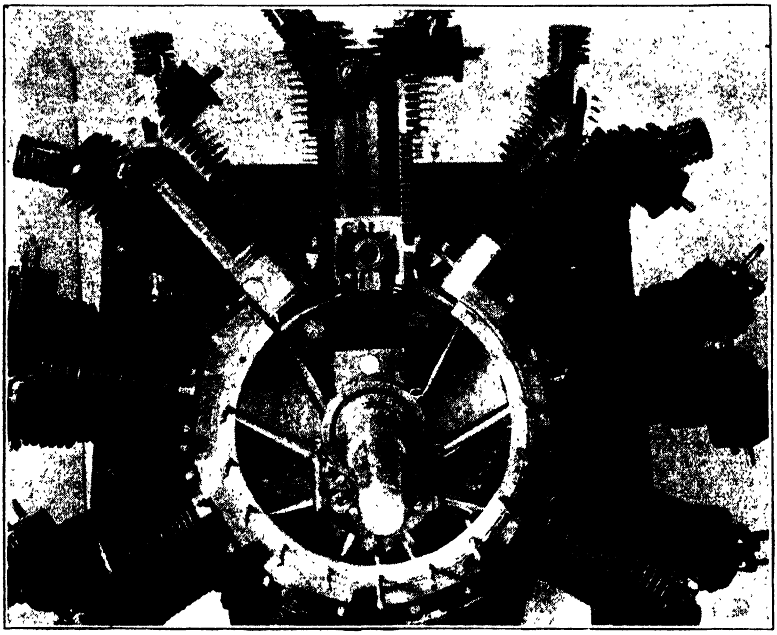


Fig. 17. Crankshaft and Connecting-Rod Assembly

Expansion and contraction of the cylinder with changes in temperature are compensated for by anchoring the forward end of the rocker housing to the push-rod housing and allowing it to rock on its support on the cylinder head. The expansion of the cylinder, therefore, causes a change in the angle of the rocker housing, slightly compressing the spring shown at the rear of the rocker housing in the illustration. The pressed steel cover for the rocker housing is held in place by two screws. The screws should be held with lock wire.

Oil Lines. Fig. 18 is a three-quarter front view of the engine, showing very clearly one of the sectioned Scintilla magnetos, the sectioning of No. 2 cylinder around the combustion chamber and exhaust valve, the exhaust valve mechanism of No. 2 cylinder, and the general arrangement of the external engine parts. Note the oil pipe draining the oil from the front and intermediate crank-case sections to the oil sump in the rear.

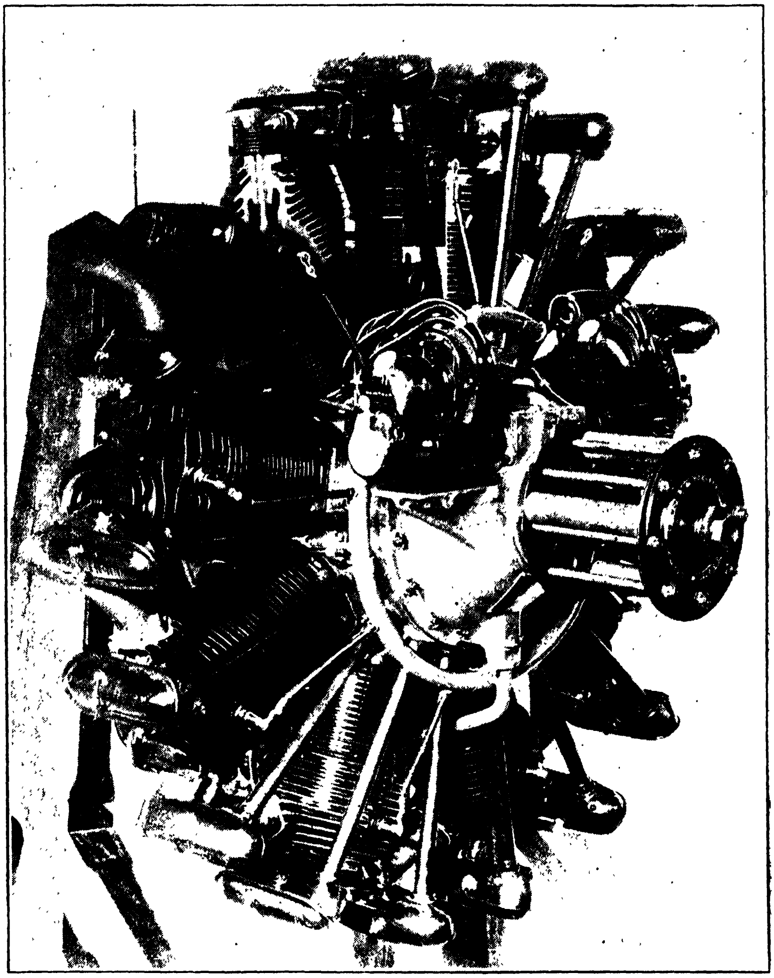


Fig. 18. Oil Pipe Draining Oil from Front and Intermediate Crank-Case Sections to Oil Sump

Propeller Hub. The propeller hub, shown in Fig. 18, is for use with wooden propellers and with old style Curtiss-Reed propellers. The newer Curtiss and other metal propellers, like the Standard Steel propellers, etc., are supplied by the propeller manufacturer with a hub of special design. The tubular ring around the crank case encloses the ignition wires.

Cylinder-Head Construction. Fig. 9 shows very clearly the construction of the cylinder. An aluminum alloy head, of special material and specially heat treated, is screwed and shrunk onto a high carbon-steel cylinder barrel. The end of the cylinder barrel meets a square shoulder in the cylinder head. The spark plug is screwed into an aluminum bronze insert in the cylinder head. Note also the special type of round-slotted nut which holds the upper end of the push-rod housing into the rocker housing, and the stud and nut which act as a clamp to lock this nut against rotation.

Stromberg Carburetor. Fig. 19 illustrates the Stromberg carburetor type "NAT-48," which is standard equipment on all Wright "Whirlwind" engines. It comprises a single float chamber with two floats arranged to maintain practically constant level in all positions of the airplane. This single float chamber feeds what is in effect three separate carburetors built into one body. There are three butterfly throttle valves on one shaft, one of which can be seen at the top. Three adjustments for the idle metering jet are seen opposite the butterfly valve. Through the opening in the float chamber one of the floats and its lever can be seen. The typical Stromberg mixture control or altitude control is on the right.

Carburetor Fuel Nozzles. At the upper right-hand side in Fig. 20 can be seen the strainer through which the fuel enters the float chamber of the carburetor. Horizontally through the center is the fulcrum rod for the float levers. Through the opening in the center can be seen one of the three main discharge nozzles, located in the center of the venturi shaped passage. Just below the discharge nozzle is the discharge nozzle stud, sometimes called accelerating well. The metering nozzle is located in the body of the carburetor in the passage between the float chamber and the well leading up to the discharge nozzle.

Manifold Assembly. Fig. 21 is a rear view of the completely assembled engine, without a starter of any kind. The circular plate, held in place by six studs spaced equally on a circle of 5-inch diameter, covers the mounting flange for any standard type of starter.

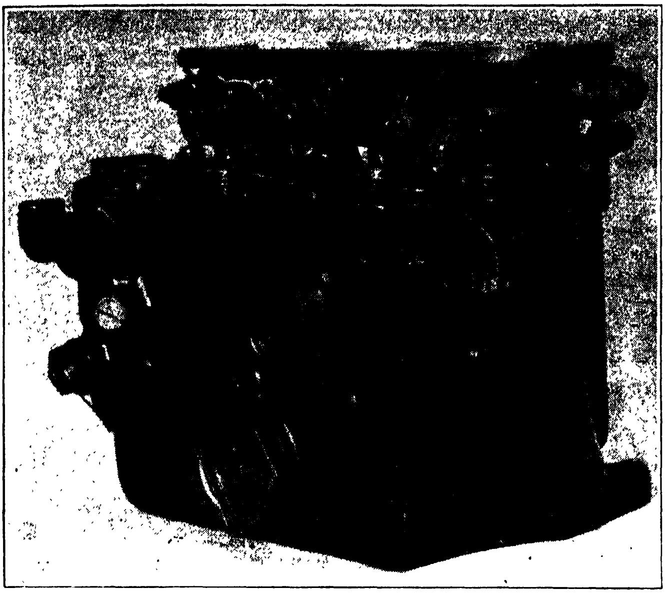


Fig. 19. Stromberg Carburetor "Nat-4B" Standard Equipment on Wright "Whirlwind" Engines

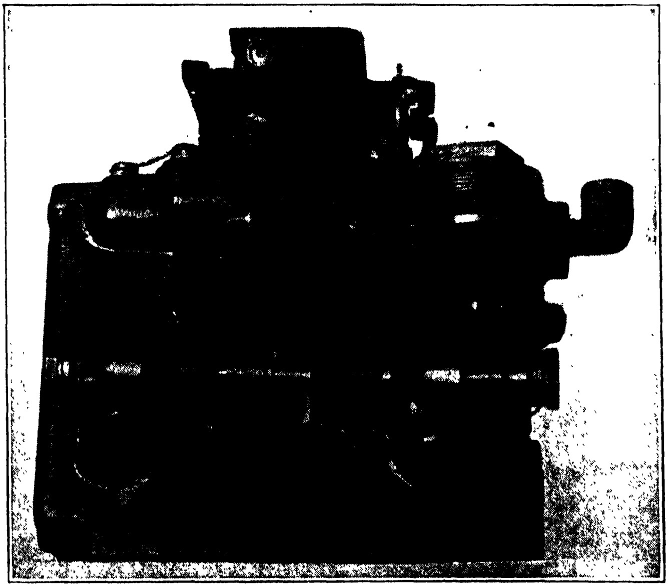


Fig. 20. Stromberg "Nat-4B" Carburetor, Showing Different Fuel Nozzles

Immediately to the left of this plate can be seen the hose connection for the oil outlet leading from the scavenging pump to the oil tank. To the left of and slightly below this oil connection are the two tachometer drives, U.S. Air Service standard, one having right-hand and one having left-hand rotation. Note that the tachometer

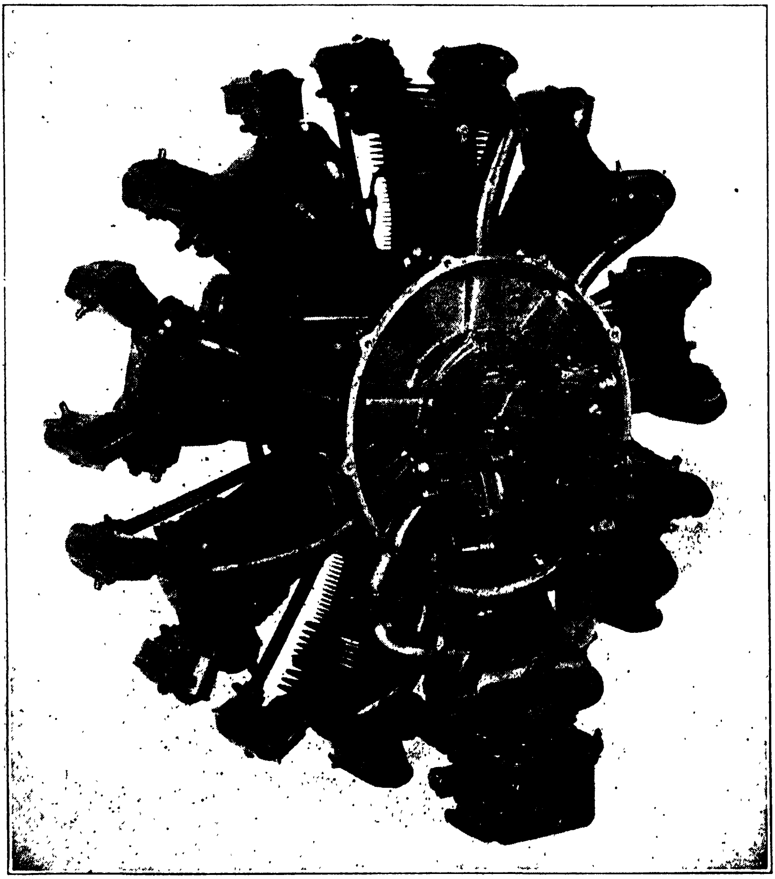


Fig. 21. Rear View of Wright Engine, Showing Manifold Assembly

drive connection which is not in use is covered by a brass cap. Immediately behind this tachometer drive can be seen the oil inlet connecting the oil tank with the suction side of the pressure pump. Directly below the tachometer drives is the oil suction pipe through which the oil is drawn from the intake manifold and oil sump, extending up to the crank-case rear section where it passes through the oil scavenging pump and on out to the oil tank, which is usually installed in the airplane directly behind the engine. Oil drains into this intake manifold and oil sump from the main crank case through a cored passage in the casting. Oil drains from the front and intermediate sections through a drain pipe which shows in the front view of the engine.

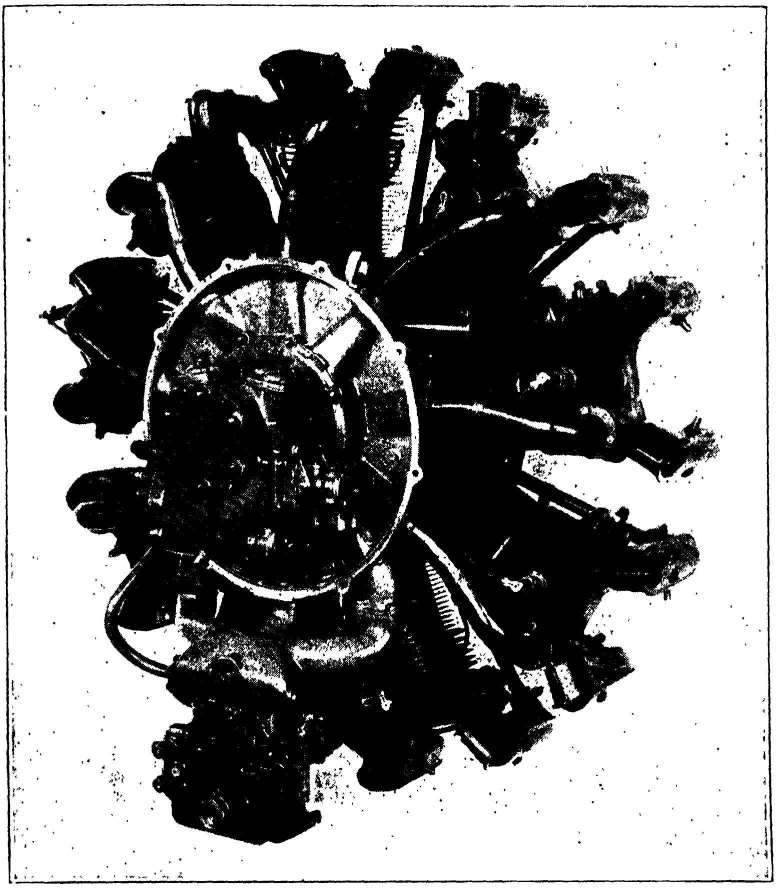


Fig. 22. Rear Crank-Case Section, Showing Oil Strainer and Fuel Pump

Immediately behind the point where the oil suction pipe is attached to the crank-case rear section can be seen the cap covering the by-pass valve, which is used to regulate oil pressure. To the right of this cap, at the bottom on the center line of the rear crank-case section, can be seen a small aluminum plug with a square head. This plug has a $\frac{1}{8}$-inch pipe thread and is replaced by the oil pressure gauge connection when the engine is installed in an airplane.

Oil Strainer and Fuel Pump. Fig. 22 is similar to Fig. 21, but shows the details of the right-hand side of the rear crank-case section. In the foreground directly above the carburetor on the side of the rear crank-case section is a steel cap, having a square lug and a slotted brass plug in the center. This cap covers the recess in the casting which encloses the oil strainer and may be removed for cleaning. Directly above and slightly forward of this cap is the Wright engine-driven fuel pump, an accessory which is not included in the standard equipment of the engine. The two splined nuts shown at the top of the crank-case rear section also represents non-standard equipment. These are the two gun control drives for synchronizing the fire of machine guns through the propeller and are of the U.S. Navy Nelson type. This view of the engine also shows very clearly the location of the intake pipes, which are clamped against the intake port of the cylinder by means of a heavy steel flange and a fiber washer and which are sealed by a packing nut and a soft rubber packing ring at the point where they enter the crank case. Viewed from the rear, the rotation of the engine is clockwise. Counting the cylinders clockwise, it will be noted that an electro thermocouple is mounted on cylinder No. 5. The electro thermocouple is quite a satisfactory method of determining cylinder temperature under various conditions of operation. At the rear of the main crank case on either side of No. 1 cylinder can be seen two lifting eyes which are screwed in the place of the two crank-case breathers when the engine is to be lifted or handled. Note that the flange for mounting the engine in the airplane is a part of the main crank case and contains eight bosses drilled for the bolts which hold the engine in the engine mount in the airplane.

THE WRIGHT "GYPSY"

The "Gypsy," Fig. 23, is a 4-cylinder vertical air-cooled engine, developing 90 horsepower at 1900 revolutions per minute and 100 horsepower at 2100 revolutions per minute. The four cylinders are arranged in line as in the ordinary automobile engine. This feature of the design is an important one to manufacturers and owners of light planes as the in-line arrangement of the cylinders materially reduces the head resistance of the plane, with consequent economy in fuel consumption. The cylinders are cast iron with heads of aluminum, and are cooled by the movement of air across and around the cooling fins on cylinder heads and barrels. The crank case is of modern aluminum castings and is of the "wet-sump type" in which oil for fifteen hours of flying can be carried. This eliminates the necessity for an oil tank in the airplane structure. The entire design of the engine is marked by great simplicity and low manufacturing and maintenance costs.

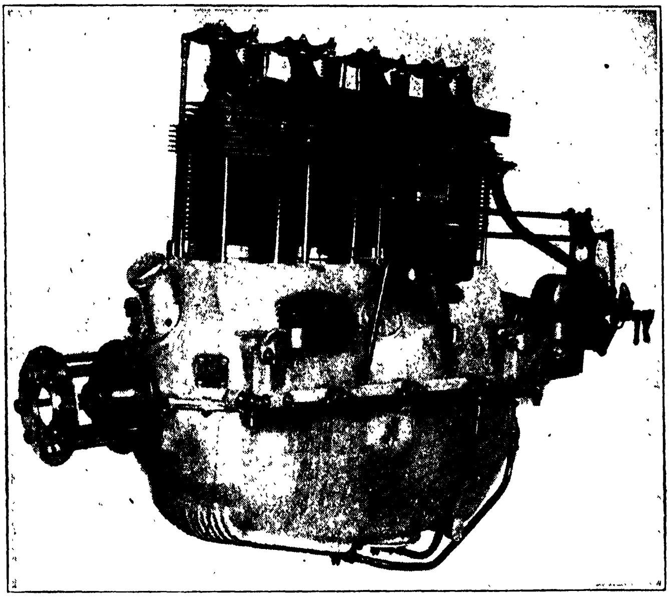


Fig. 23. Side View of Wright "Gypsy" Engine—90 Horsepower

The "Gypsy" was designed by Major F. B. Halford, who is well known as the designer of the A.D.C. "Cirrus," and Captain G. DeHavilland. The first engines of this type were manufactured early in 1927. One of these was installed in the "Tiger Moth," the fast little single seater developed by the DeHavilland Company. This plane attracted world-wide attention, reaching a speed of 200 miles per hour in its trial flights and giving a really remarkable performance. The "Gypsy" engine installed in that plane was equipped with high compression pistons—$5\frac{1}{2}:1$—and developed 150 horsepower at 3000 revolutions per minute.

Standard "Gypsy" engines, with compression ratio of 5:1, have had hundreds of hours in the air in various types of Moths. A "Gypsy Moth" won the greatest classic air event in England—the 1100-mile race for the King's cup. Another established a new altitude record for two-seater light planes by climbing to a height of 20,000 feet in 70 minutes. Still another broke the world's light- plane endurance record by remaining continuously in the air for 24 hours.

The Moth has been one of the most important elements contributing to the widespread aeronautical activity of private individuals and organizations in England. It is standard equipment in the many civil aviation clubs which have been established in all parts of the British Empire. It is widely used by British aviation enthusiasts for sport and business flying as well as by many European Governments in training student pilots.

SPECIFICATIONS

Type—4-cylinder, vertical, air-cooled, direct drive
Rotation—Left-hand tractor
Bore—114 mm. ($4\frac{1}{2}$ inches approximately)
Stroke—128 mm. ($5\frac{1}{16}$ inches approximately)
Capacity—5,266 c.c.
Normal b. hp.—90 hp. at 1900 r.p.m. (rated hp. 85 at 1900 r.p.m.)
Maximum b. hp.—100 hp. at 2100 r.p.m. (approximately)
Compression ratio—5:1
Displacement—319 cu. in.
Weight—Engine complete with propeller hub, etc., 285 lbs.
Fuel consumption—0.59 pint per b. hp. per hour
Oil consumption—$\frac{1}{2}$ to $\frac{3}{4}$ pint per hour.

PRATT AND WHITNEY AVIATION ENGINES

One of the earliest and most dependable designs of the fixed radial air-cooled aviation engine is that of the Pratt and Whitney Company. To all intents and purposes, the aviation engine is quite similar in operation to the four-stroke cycle automobile engine. The reader should keep this in mind at all times. The various illustrations will show how the mechanical features provided are designed to accomplish the same ends which are secured by the better understood automobile engine features.

There are a number of models of the Pratt and Whitney engines. The larger types, Fig. 24, are known as the "Hornet" engines, and develop horsepower from approximately 500 to 600, depending upon the model. The smaller engines are known as the "Wasp" engines and are quite similar in design to the Hornet engines.

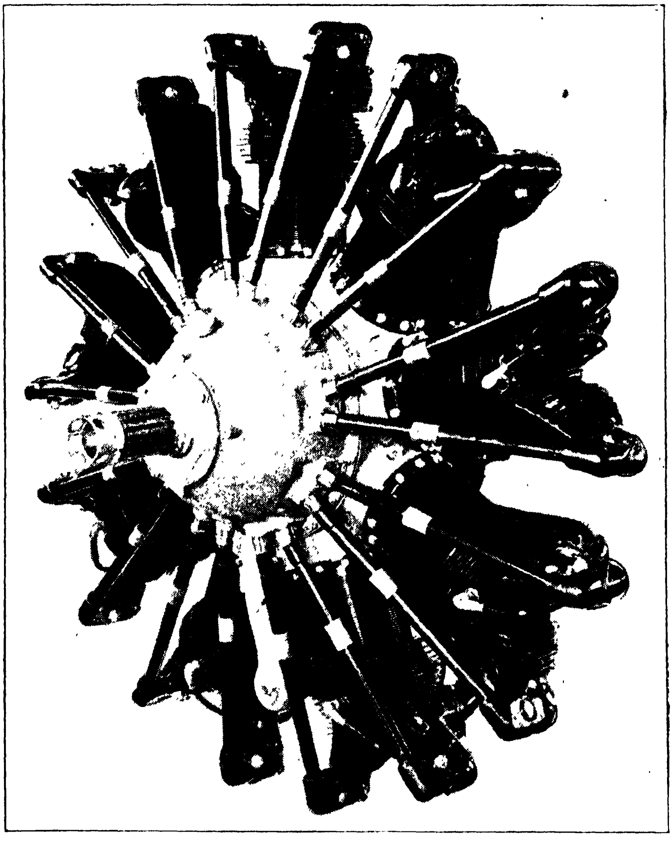


Fig. 24. Pratt and Whitney Series "B" Hornet — 575 Horsepower at 1950 Revolutions per Minute; Weight 810 Pounds

The Wasp "Junior," Fig. 25, is rated at 300 horsepower and the Wasp "C," is rated at 420 horsepower. The Wasp "C" and the Hornet engines are all built in two styles, the one being a direct drive for the propeller, and the other types being a two to one gear reduction which permits of a reduced propeller speed with an increased tractive effort.

The Wasp "Junior" is designed so that 80 per cent of its parts are interchangeable with those of the Wasp "C." The cylinders, pistons, and connecting rods are reduced in size, but the central section of the engine is quite similar to the larger job.

The specifications as given for the Wasp "Junior," the Wasp, and the Hornet indicate the difference between the direct drive and the two to one reduction gear drive. Except for the difference with reference to the decreases in size of certain parts of the Wasp "Junior" as compared to the Wasp "C," the technical description of the Wasp and Hornet parts apply to any of the Wasp and Hornet engines. The general principles of design are the same in all models.

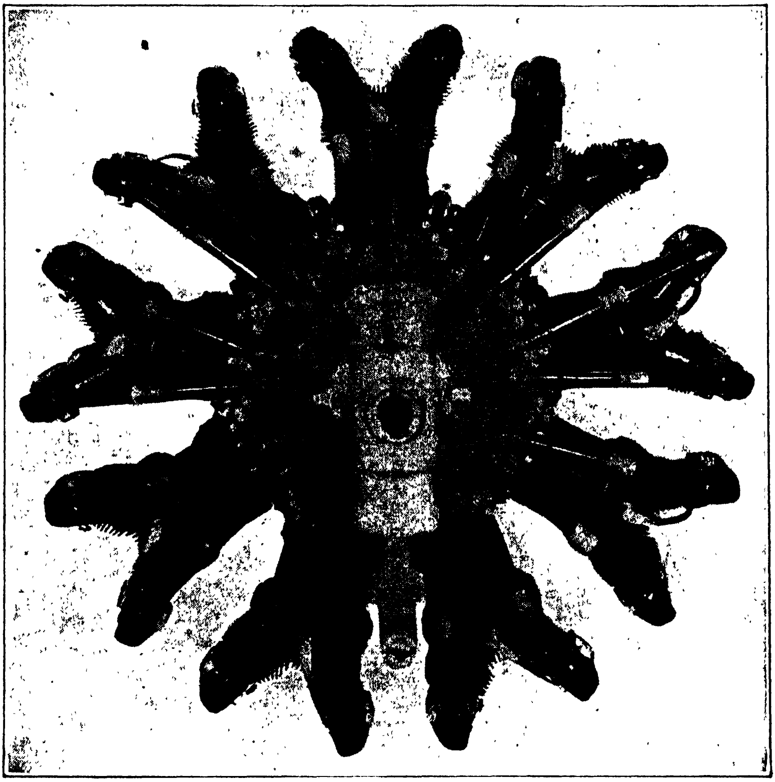


Fig. 25. Full Front View of the 300-Horsepower Pratt and Whitney Wasp "Junior"
This model is of 985 cubic inches displacement, weighs 550 pounds, and is $45\frac{3}{4}$ inches overall in diameter. It is essentially the Wasp engine with a new power section and is rated at 300 hp. at 2000 r.p.m. It has an equal bore and stroke of $5\frac{3}{16}$ inches.

The engines are made in several sizes in order to meet the demands of military and commercial aviation. The larger sizes have played a very definite part in the development of commercial aviation. Many of the commercial transport and mail planes are powered with these engines.

Cylinders. The cylinders, Fig. 26, which are built up of a forged steel barrel and cast aluminum head with integral valve mechanism housings, are largely responsible for the efficiency of the engine. The cylinder heads are provided with vertical fins which give the maximum cooling to the combustion chamber and to the valves. The integral rocker mechanism housings are a special feature of all Pratt and Whitney engines and make possible the complete inclosure of the rocker mechanism in a tight compartment. They

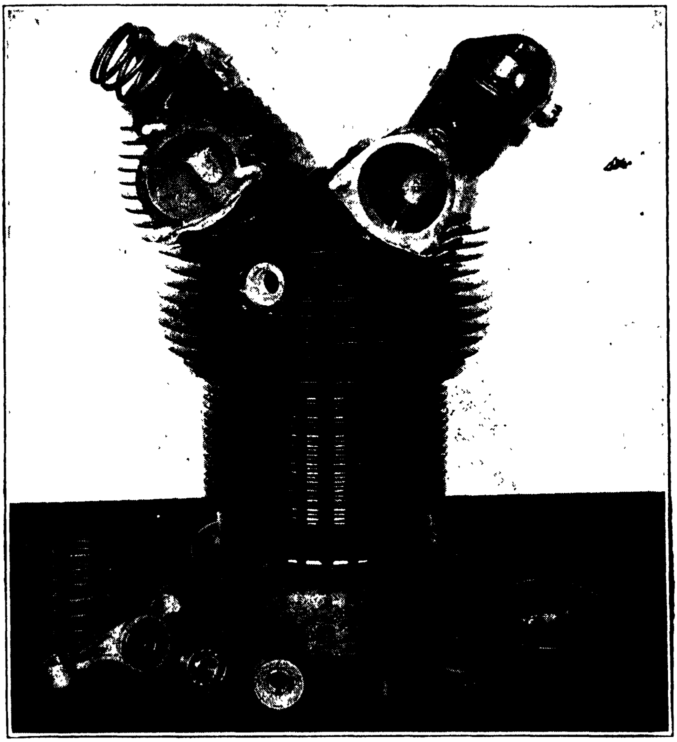


Fig. 26. Pratt and Whitney Cylinder and Valve Parts

WASP JUNIOR SPECIFICATIONS

Type	Fixed Radial Air-Cooled
No. of cylinders	9
Bore	$5\frac{3}{16}$ inches
Stroke	$5\frac{3}{16}$ inches
Displacement	985 cu. in.
Compression ratio	5 : 1
Guaranteed hp. at 2000	300
Weight (without special equipment) approx	550 lbs.
Length overall	$41\frac{1}{32}$ inches
Diameter overall	$45\frac{3}{4}$ inches
Fuel consumption (lbs. per hp. hour) not more than	.55
Oil consumption (lbs. per hp. hour) not more than	.035

WASP SPECIFICATIONS

Type	Direct Drive Fixed Radial Air-cooled	2-1 Reduction Gear Drive Fixed Radial Air-Cooled
No. of cylinders	9	9
Bore	5.75 inches	5.75 inches
Stroke	5.75 inches	5.75 inches
Displacement	1344 cu. in.	1344 cu. in.
Compression ratio	5.25 : 1	5.25 : 1
Military guaranteed hp. at 2100	450	425
Commercial guaranteed hp. at 2000	420	
Commercial guaranteed hp. at 2100		420
Weight (without special equipment) approx	688 lbs.	755 lbs.
Length	$42\frac{9}{16}$ inches	47 inches
Diameter	$50\frac{5}{8}$ inches	$50\frac{5}{8}$ inches
Fuel consumption (lb. per hp. hr.) not more than	.55	.60
Oil consumption (lb. per hp. hr.) not more than	.035	.035

are not subject to leaks or failure through the improper adjustment of attaching the bolts.

Crank Case. On the direct-drive engines, the crank case is made up of a nose section, see Fig. 28, main section, blower section, and the rear or accessory section. The geared engine is identical except that the nose section is made in two parts, one of which is arranged to inclose the gearing, which is shown in Fig. 27.

HORNET SPECIFICATIONS

Type	Direct Drive Fixed Radial Air-cooled	2-1 Reduction Gear Drive Fixed Radial Air-Cooled
No. of cylinders	9	9
Bore	6.25 inches	6.25 inches
Stroke	6.75 inches	6.75 inches
Displacement	1860 cu.in.	1860 cu.in.
Compression ratio	5 : 1	5 : 1
Guaranteed hp. at 1950 r.p.m.	575	550
Weight (without special equipment) approx	800 lbs.	875 lbs.
Length overall	$44\frac{9}{16}$ inches	48 inches
Diameter overall	$56\frac{3}{4}$ inches	$56\frac{3}{4}$ inches
Fuel consumption (lb. per hp. hr.) not more than	.55	.60
Oil consumption (lb. per hp. hr.) not more than	.035	.035

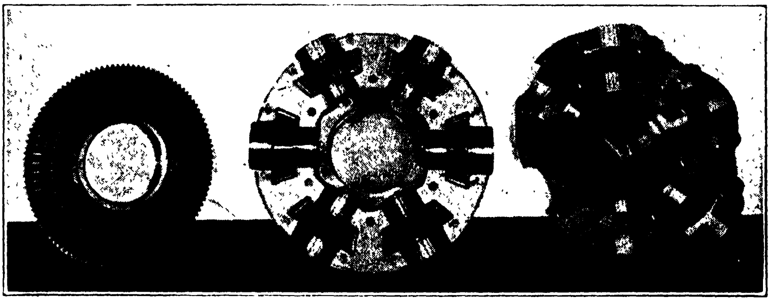


Fig. 27. Pratt and Whitney Wasp Reduction Gearing

A distinctive feature of the Wasp and Hornet engines is that the main crank case of forged aluminum alloy is built in two parts. The main section is divided on the center line of the cylinder, thus making possible the use of forgings which have a strength approximately one and one-half times that of the best heat-treated castings. The nose section of the direct-drive Wasp is also an aluminum forging. The nose section, Fig. 28, carries the valve tappet guides and incloses the cam.

The blower section immediately behind the main section carries the centrifugal supercharger used as a distributor in all Pratt and Whitney types. This section also provides the mounting lugs by which the engine is attached to the airplane with nine bolts. The rear section of cast aluminum alloy carries all of the accessories, including the carburetor, magnetos, starter, generator, fuel pump and oil pump.

Crankshaft. The crankshaft of both the Wasp and Hornet is of the single-throw type two-piece construction of distinctive Pratt and Whitney design. It is machined from forged alloy steel. It is shown assembled in Fig. 29 and disassembled in Fig. 30.

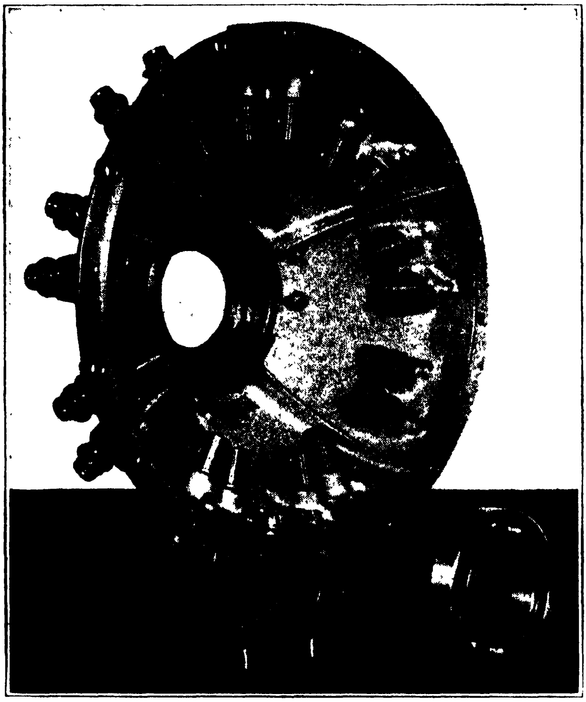


Fig. 28. Wasp Engine Forged Nose, Section and Bearing

Connecting Rods. The master rod is of one-piece construction, which was first introduced into the United States in production engines by the Pratt and Whitney Aircraft Company. All rods are of I-section. The crankpin bearing is designed to give ample bearing surface and maximum durability. The master rod, Fig. 31, has another rod attached. Seven rods are required to complete the assembly.

Bearings. The crankshaft is supported on three anti-friction bearings, there being two roller bearings, one on each side of the crank, Fig. 29, and a deep row ball thrust bearing immediately behind the propeller. These bearings are of ample proportion, which insures long life in service.

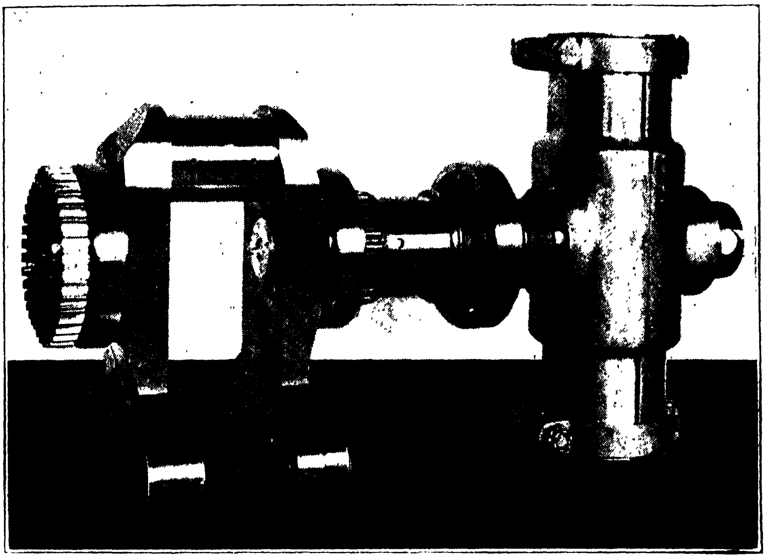


Fig. 29. Pratt and Whitney Wasp Engine Crankshaft Assembled

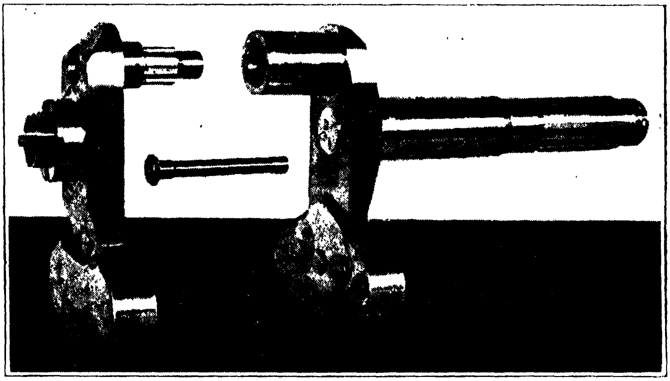


Fig. 30. Pratt and Whitney Wasp Engine Crankshaft Disassembled

Valve Gear. The cam inclosed in the nose section of the engine operates hardened-steel roller cam followers, which in turn operate the ball-bearing rockers inclosed in the cylinder heads, Fig. 26, through fully inclosed push rods. This cam automatically compensates for changes in clearance because of cylinder expansion.

The alloy steel valves are of tulip type, operated by steel rockers, carried on ball bearings. These rocker arms with their bearings have been designed for the maximum of durability. All valve parts can be removed from the cylinder merely by removing the cap covering the rocker box.

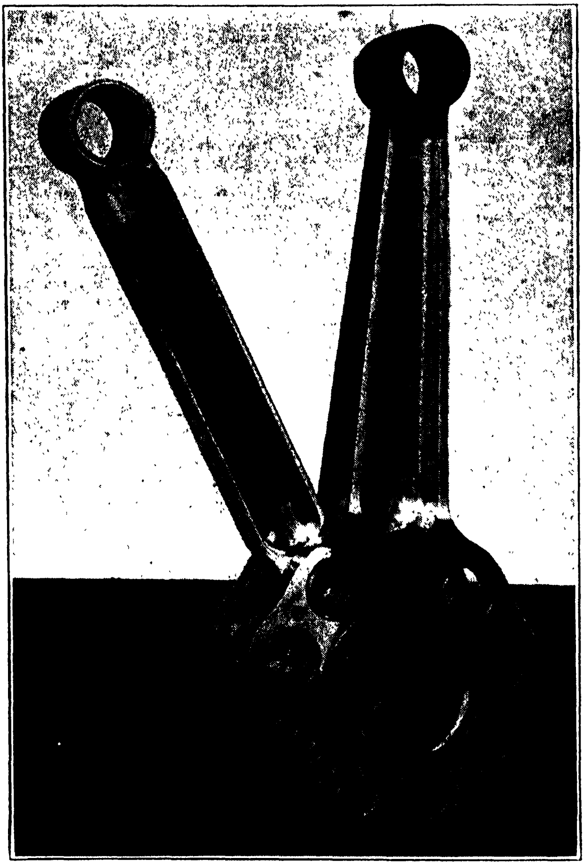


Fig. 31. One-Piece Master Rod for Pratt and Whitney Engines
This master rod carries eight link rods, one of which is attached.

Lubrication. Pressure lubrication is supplied by a gear type pump to all main bearings of the engine. A fine mesh screen is provided which thoroughly cleans all incoming oil. This screen is readily removable from the underside of the accessory compartment. A pressure relief valve maintains a uniform pressure on the system. All the oil is drained to a single sump located between the two lower cylinders, which is scavenged by another gear pump, the oil being returned to an external tank. A drain is provided in this sump as well as a screen in the scavenging line.

Ignition. Dual magneto ignition is provided by two Scintilla Type "9" cylinder magnetos, operating on two independent sets of spark plugs.

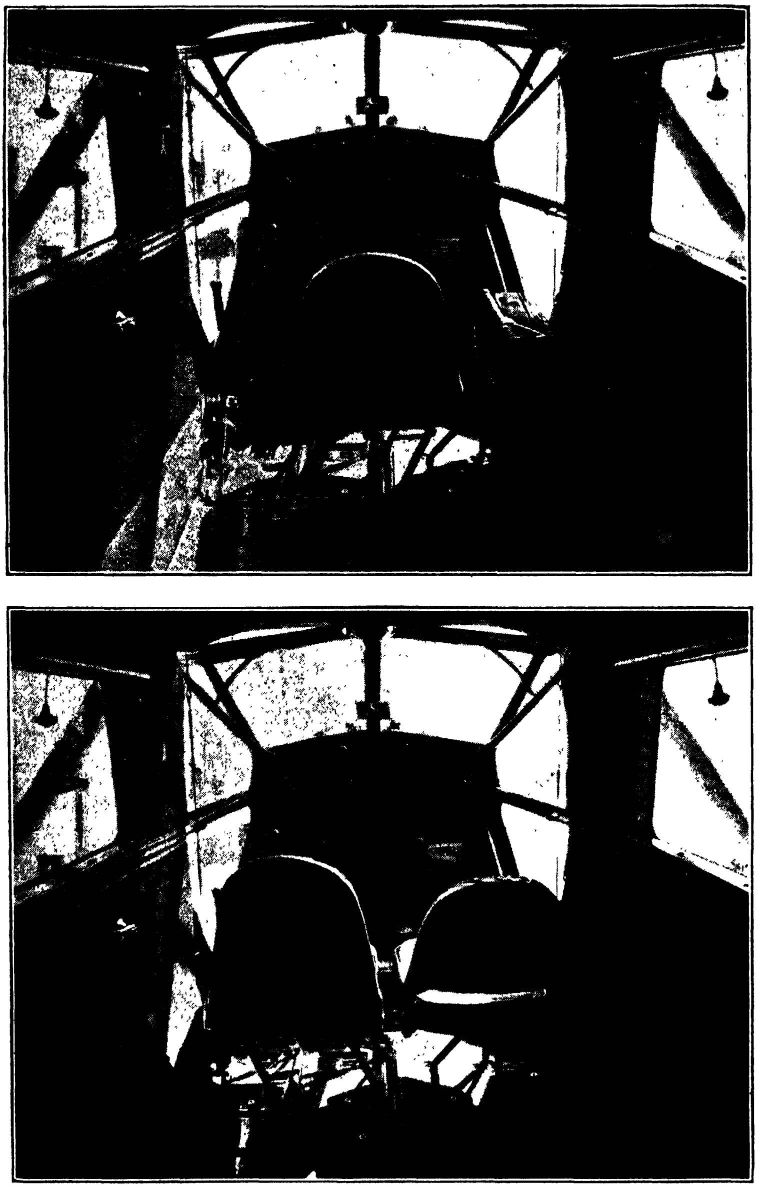
Carburetor. A dual Stromberg carburetor is mounted on the rear section of the crank case, feeding the mixture into the distribution system.

Distribution System. Every Pratt and Whitney engine is provided with a General Electric rotary supercharger, used to provide proper fuel mixture distribution. With a suitable gear ratio, it is possible for certain specialized purposes to provide a reasonable amount of supercharging without additional weight or complication.

Induction System. To provide for all weather operation, a universal hot spot and intake heater is furnished as standard equipment on every engine. By utilizing exhaust gases, the mixture is heated after it passes through the carburetor. The amount of heat is regulated by an adjustable valve. In addition, to prevent ice formation in the carburetor, heat is introduced in the air intake horn as required.

Accessories. All the accessories are grouped at the rear of the engine, protected by the cowling from weather, and providing simplicity in control, hook-up, and engine cowling.

Reduction Gearing. On the geared type engines a 2-1 propeller speed reduction is provided by a gear unit of Pratt and Whitney design, Fig. 27. This gearing is of the concentric type with the power transmitted through six pinions linked together by a patented automatic equalizer. By this arrangement the driving torque is evenly divided between the pinions, insuring long life. The prime reason for a gear reduction is to secure slow propeller speed with greater tractive force.



MAHONEY-RYAN AEROPLANE SHOWING SEATS, CONTROLS, AND INSTRUMENTS

AVIATION ENGINES

PART II

LeBLOND AVIATION ENGINE

Crankshaft. The 5-cylinder 60-horsepower LeBlond radial air-cooled engine is shown in Fig. 32. The single-throw crankshaft, Fig. 33, is drop-forged in one piece from nickel chromium steel. It is finish ground allover and counterbalanced by bronze weights which shoulder against two lugs on opposite sides of each crank cheek. These weights are located by screws, which are permanently locked.

The crankshaft is supported upon two ball bearings, the one for the front being assembled later as it is locked endwise in the crankcase cover to carry the propeller thrust. The inner race of each bearing is locked on the shaft by a nut, and shoulders against a ring spacer which provides sufficient room for ample fillets between the crankshaft journal and cheek. The bearings are lubricated by splash.

For mounting the propeller hub, the crankshaft is provided with a tapered end, Fig. 34, in which there is a key slot and two tapped holes for the screws which retain the key. The shaft is hollow its entire length, the hole in the rear journal being made larger, and it is closed at the inner end by a Welsh plug. The cam drive shaft, which forms a part of the gear-case assembly, pilots into the end of the rear journal and is driven by the lugs which fit into the slot at the end of the crankshaft. These lugs are off center so it is impossible to assemble either crankshaft or gear case except in the correct position, once the valve timing is adjusted. Oil enters the crankshaft under pressure through the hollow cam drive shaft. It then flows to the hollow crank pin by means of a hole drilled through the rear crank cheek.

The crank pin is provided with three holes for feeding oil to the connecting-rod bearing. The two smaller holes near the end of the crank pin are so located as to match each revolution with holes in the rod bearing that leads to the link rod wrist pins. All the oil being fed to the bearings must first pass through a special cast-aluminum oil plug, which is regarded as one of the interesting features of the design. This plug is so arranged that any heavy particles of dirt in the oil, which are naturally thrown to the outside by centrifugal force, become permanently trapped and are thereby prevented from passing through the bearing. Undoubtedly, this is an important factor in the unusual long life of the connecting-rod bearing. The oil plug is held in position by a cotter pin and it can be quickly removed at any time for cleaning.

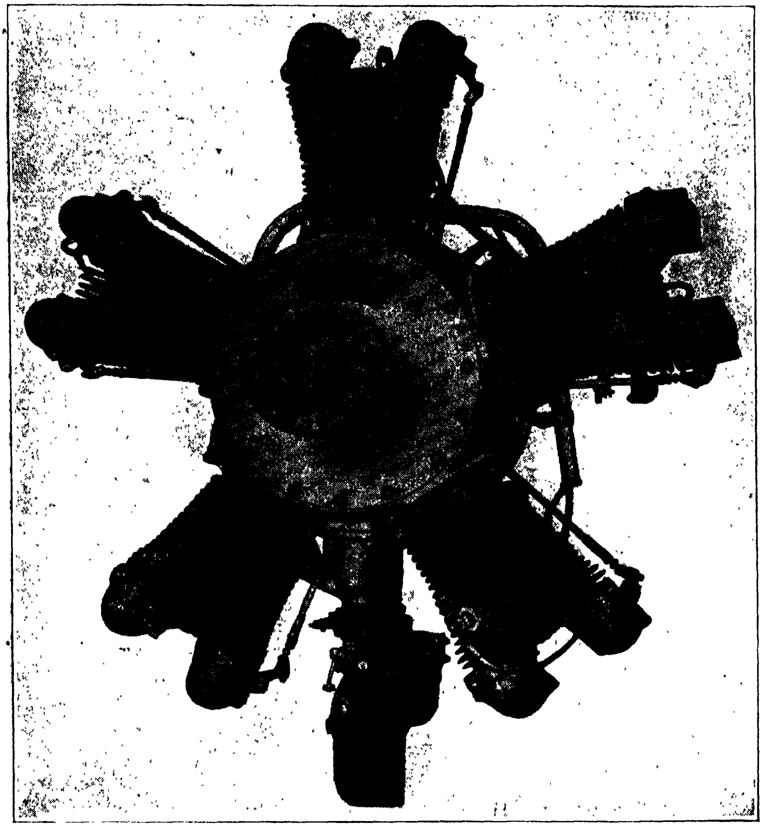


Fig. 32. Front End of the LeBlond "60" 5-Cylinder Fixed Radial Aviation Engine

Pistons. The pistons are of an aluminum alloy cast in permanent moulds and heat-treated to give the desired hardness. They have a full skirt and three rings above the piston pin, Fig. 35, the lower ring functioning as an oil scraper. The head of the piston is of ample thickness for cooling and is supplied as well with ribs underneath. The piston pin is hollow, the outer surface being casehardened and lapped to exact dimensions. In each end is pressed a duralumin plug to prevent the piston pin from scoring the cylinder walls.

Connecting Rods. Articulated type connecting rods of an extremely simple design are employed. The rods are made from nickel chromium steel drop-forgings, being finished where necessary, or for the special purpose of removing excess weight. By leaving the skin of the forging on the H-section of the shanks, considerable advantage in strength is the result.

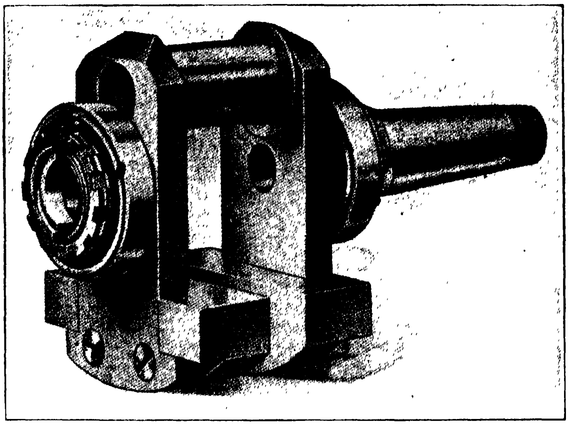


Fig. 33. Crankshaft and Ball-Bearing Assembly of the LeBlond "60"

The master connecting rod and cap have a full bearing upon the crank pin. The babbitt is applied directly to the steel and the two are bored to size. The cap is closely fitted to the master rod with a stepped joint and they are held together and doweled by four nickel steel bolts. These bolts also securely lock the wrist pins in place, thus eliminating numerous small parts that are so frequently used. The bolts have thin square heads which rest against shoulders to prevent turning, and they are made tight by long hexagon nuts locked by cotters.

The link rods are interchangeable and would otherwise be reversible if it were not for the necessity of placing the end which has the

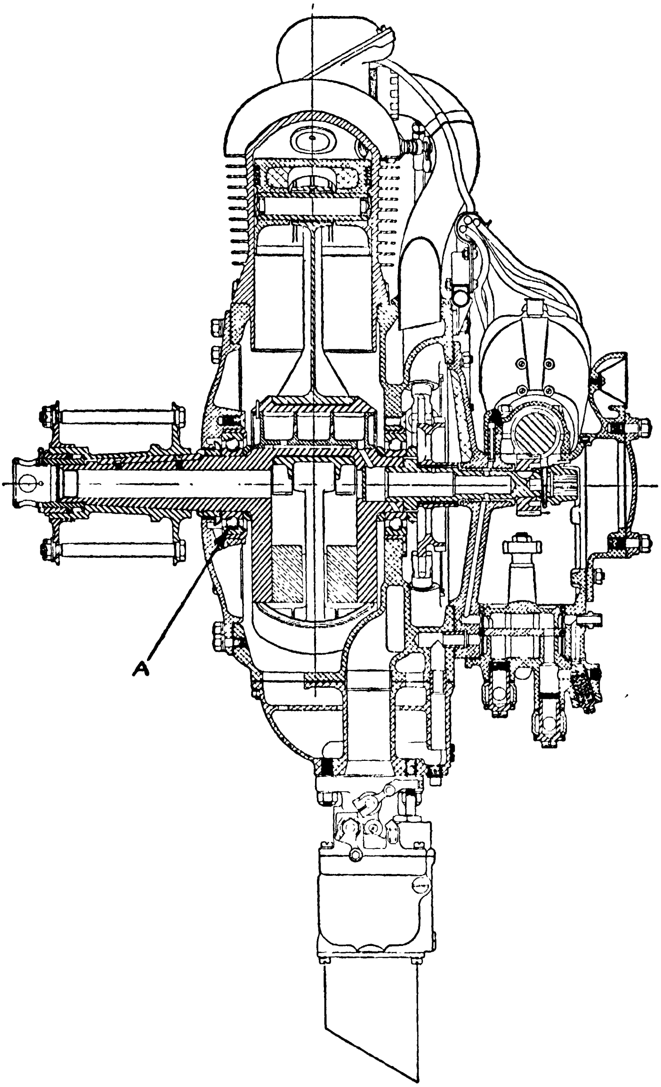


Fig. 34. Sectioned View of the LeBlond "60," Showing Crankshaft, Connecting Rod, Induction System, Magneto Drive, and Propeller Hub

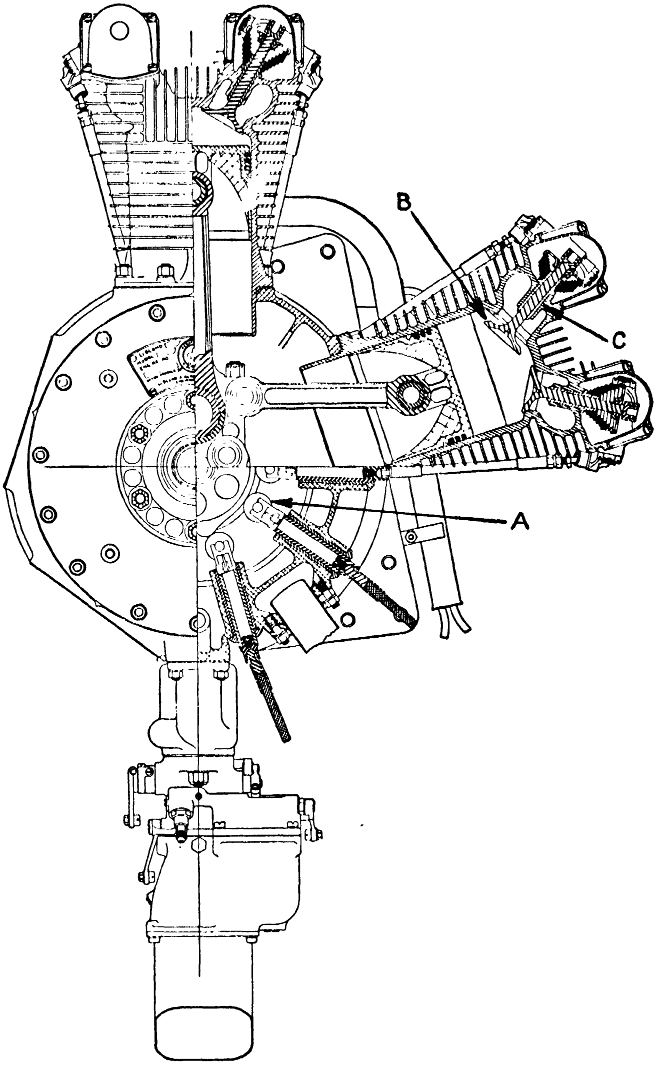


Fig. 35. Sectioned View of the LeBlond "60," Showing Cylinder and Piston in Section with Valve-Operating Mechanism

oil hole to the outside to permit splash lubrication of the bearings. The bronze bushings which are pressed into each end of the link rod and into the upper end of the master rod are alike.

The wrist pins are hollow and the ends are closed by Welch plugs that are permanently secured by peening. The half-round slots in the wrist pins fit fairly close around the bolts, the undercut steps in the bolt being used in conjunction with drilled holes which line up with holes in the master rod and cap to supply oil under pressure to the interior of the hollow wrist pins. Midway on the wrist pin is a hole which leads to the link-rod bushing. All wrist pins are interchangeable. The outer surface is casehardened, and exact dimensions together with a near-perfect finish are obtained by lapping.

Crank Case. The crank case, Figs. 34 and 35, is a heat-treated aluminum casting of high tensile strength. It has a large opening in front through which the crankshaft and connecting rods may be inserted as an assembly. This opening also serves as a pilot for the crank-case cover, the latter being held in place by fifteen studs. A similar opening with ten studs at the rear is the provision for attaching the gear-case assembly; and the hollow dowel through which the oil passes to the scavenger pump serves as a locater.

The integral inlet manifold is a separately cored passage in the form of a ring with openings to receive the inlet pipes and one which connects with the carburetor through the crank-case oil sump. Hence there are few joints which might possibly develop leaks, and the oil is cooled by the incoming gases. The wall central with this inlet manifold ring provides a support for the rear crankshaft bearing. The ball bearing is supported directly on a steel sleeve which is pressed into the crank case and held in place by three countersunk head screws permanently locked from turning.

Cast-iron bushings with holes ground to close limits are pressed into the crank case to serve as guides for the cam followers. These cam followers are in the same transverse plane, this being made possible by the use of the single cam ring.

The cam followers *A*, Fig. 35, are made from an alloy steel, heat-treated to give both hardness and toughness. The followers are drilled for lightness and receive at the outer ends a push-rod ball socket which is pressed into place. A special lock screw serves to keep the follower from turning about its axis and to prevent any possibility of its dropping out when the push rods are not in place. At the inner end of the cam follower is a slot to guide the hardened roller and a half-round bearing for its two small journals. The safety wire is merely to insure that the roller will not drop out of place when it is not in contact with the cam, as in assembly.

On the lower side of the crank case, the finished pad with its studs provides a means of attaching the oil sump. Excess oil drains into this sump from the crank case both front and rear, and from there the oil is drawn through the hollow dowel, locating the oil sump, as it is being returned to the scavenger pump.

The crank case and the parts which go to make up the assembly are shown in Figs. 34, 35, and 36. All studs are made from alloy steel, and the threads are held to close limits to insure good fits.

Crank-Case Cover Assembly. The opening at the front of the crank case is closed by a forged duralumin cover, which is heat-treated to obtain high tensile strength. This cover pilots into the crank case and is held in place by fifteen studs. The front crankshaft ball bearing *A*, Fig. 34, is supported by the cover in a steel sleeve that is held in place by three countersunk head screws permanently locked from turning. This bearing is held endwise on the outer ball race to locate the crankshaft and to carry the thrust load of the propeller. Between the bearing and the crankshaft nut is an oil thrower which together with threads in the front of the crank-case cover prevents oil seepage to the outside. The nut on the crankshaft which screws up against the inner race of the ball bearing is locked from turning by the propeller hub key, since it extends into one of the turning slots on the nut. On the front of the crank-case cover is a name plate and four studs which are to be used for attaching a support for the forward end of the cowling.

Cylinders. The cylinders are cast from the finest grade of nickel iron in single units with cooling fins integral. Each cylinder is held to the crank case by eight studs which pass through the hold-down flange. The inner end of the cylinder barrel extends into the crank case a distance sufficient to prevent over-oiling of the lower cylinders.

The outer surface is finished with a glossy black stove enamel capable of resisting heat. This adds greatly to the appearance of the cylinder and to the heat dissipating qualities as well. The inside and also the outer portion of the cylinder barrel below the flange is finished allover. The bore is held to close limits and given an excellent finish by honing. The combustion chamber is spherical in shape and provides seats for the interchangeable inlet and exhaust valves *B*, Fig. 35, which are inclined at an angle of 30 degrees to the cylinder axis.

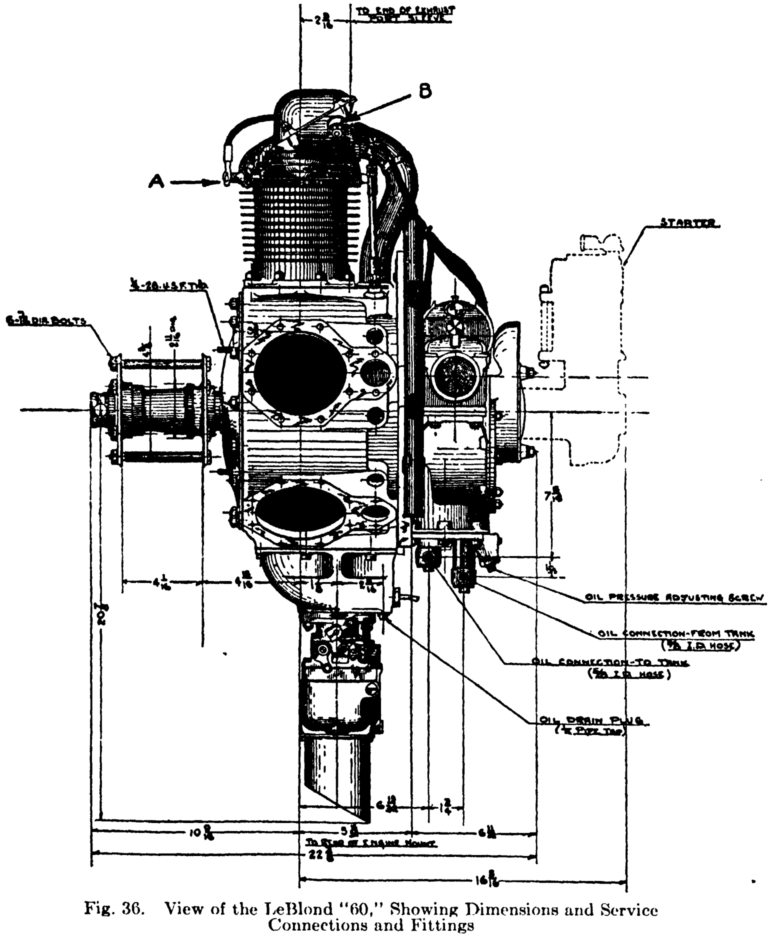

TO END OF EXHAUST PORT SLEEVE
B
A
STARTER
6-DIA BOLTS
-20 U.S.F.THD.
7
OIL PRESSURE ADJUSTING SCREW
OIL CONNECTION-FROM TANK (I.D. HOSE)
OIL CONNECTION-TO TANK (I.D. HOSE)
OIL DRAIN PLUG (PIPE TAP)
10
5
TO REAR OF ENGINE MOUNT
22
16

Fig. 36. View of the LeBlond "60," Showing Dimensions and Service Connections and Fittings

The valves are silchrome steel with 45-degree seats. Removable valve guides *C*, Fig. 35, are pressed into the cylinder. The interchangeable valve springs are of the volute ribbon type, holding about 60 pounds at valve open position. Each valve is held by a split retainer seating with a taper in the valve spring collar, and a wire safety clip circles the valve stem below the collar to prevent the valve from dropping into the cylinder.

Two spark plugs *A* and *B*, Fig. 36, are provided at opposite positions, front and rear. The inlet and exhaust valve ports face the rear, thus making the arrangement simple for the attachment of an exhaust collector ring.

Threaded sleeves are screwed into each port and protrude sufficiently to receive an annular packing nut. The inlet pipe need not be disturbed while removing a cylinder. The valve rockers are pressed on to the square ends of the rocker shafts, which are supported in bronze bushings pressed into the cylinder. Lubrication of these bushings as well as the enclosed valve parts is accomplished through a fitting from the outside.

Propeller Hub. The propeller hub, Figs. 32 and 36, is driven through a key on the tapered end of the crankshaft. A special nut with holes for the turning bar draws the hub up tightly on the taper. At the outer end of the hub is a puller nut against which the back face of the flange on the propeller hub nut bears when removing the hub from the crankshaft. These two nuts are provided with means for locking against turning when the hub is once in place. The propeller hub flange pilots on the front of the hub, and the propeller pilots on both hub and flange and is held between the two by six special bolts and nuts.

Gear Case. The gear case *B*, Fig. 37, is assembled as a unit before it is incorporated into the final assembly of the engine. The case itself is an aluminum casting, having a round flange and pilot where it is attached to the crank case. In the central wall are two bosses, each receiving bronze shoulder bushings pressed in from the ends. On top is a pad for supporting the magneto drive-shaft housing, and in line with it at each side is a bracket for supporting a magneto. Below is a flange for attaching the oil pump, the cylindrical opening in the case serving as the outer housing for the oil pump when the latter is in place. Sufficient space is provided for assembly and adjustments by the opening at the rear.

The central boss supports the cam drive shaft. Oil enters the interior of this shaft through a hole which is in line with the space between the ends of the bushings, and it passes directly through into the end of the crankshaft. The end of the cam drive shaft pilots into the end of the crankshaft and the two off-set lugs engage with the slot as a means of drive. The cam is provided with a bronze bushing, since it floats on the cam drive shaft. Oil is fed directly to the bushing through holes in the wall of the cam drive shaft. The cam ring operates all valves and when the gear case is in place, these cams are in line with the cam follower rollers.

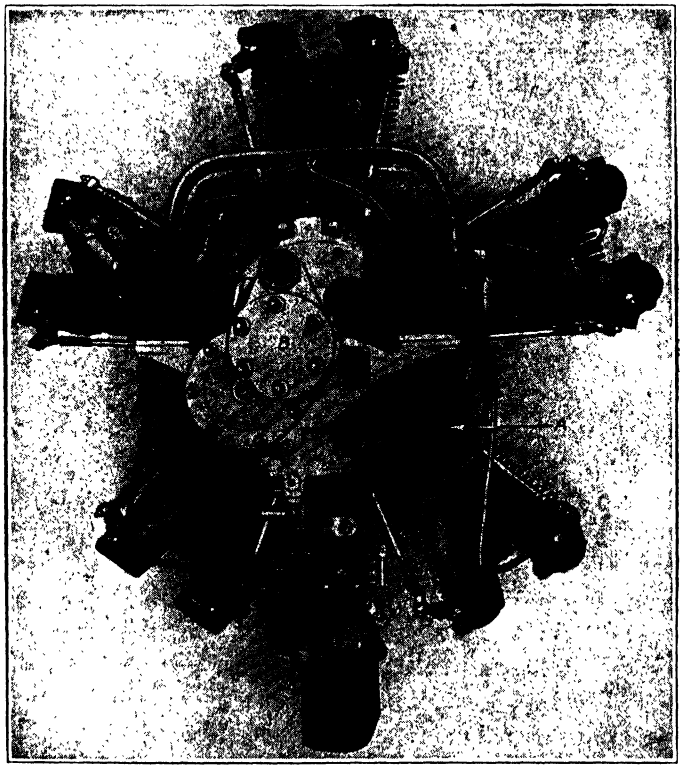


Fig. 37. Rear View of the LeBlond "60," Showing Mounting Plate, Gear Case, Magnetos, Carburetor, Rocker Arms, and Other Features

At the rear end of the cam drive shaft is a spiral gear driven through a key. The nut which holds the gear up against a shoulder on the shaft is held from turning by a taper pin secured by a cotter. This nut is furnished with a female splined end to receive a starter.

This spiral gear drives at half engine speed another spiral gear which pilots on the hub of the cam timing flange. The latter is keyed to the idler shaft and driven by four special screws which set the valve timing through the selection of a differential series of holes in the two pieces. When the timing is set, the hub of this flange is clamped against a hardened washer which rests against a shoulder on the idler shaft and also takes the gear thrust on the flange of the bronze bushing in the gear case. The clamping is done by a special nut provided with a drive for a tachometer cable. At the opposite end of the idler shaft is a gear meshing with the gear which is an integral part of the cam. The idler shaft bushings are lubricated by a pressure line in communication with the annular space between the cam drive-shaft bushings.

Above and at right angles to the cam drive shaft lies the magneto drive shaft. Central on this shaft is a gear driven by the spiral gear which is located at the rear end of the cam drive shaft. Shoulder bushings are slipped upon the magneto drive shaft from each end. They are located between the two halves of the housing and prevented from turning by dowels. These bushings are fed with oil under pressure, and at each end of the shaft is an oil thrower as well as threads in the housing to return the excess oil to the gear case.

Gear-Case Cover. The cast aluminum cover which closes the opening at the rear of the gear case is located by two dowels and held in place by eight studs. In addition to the three long studs in the gear case, three other studs are fixed in the cover to permit either the mounting of an electric starter or the cover which closes the opening central with the crank axis. In line with the idler shaft axis, a special stud is screwed and locked in the gear-case cover to provide a means of attaching a standard tachometer connection. The breather, which is cast integral with the cover, has baffles to retain oil spray and a conical screen at the outside opening to keep out dirt.

Oil Pump. The oil pump is built up of three main units—a lower body, an upper body, and a plate. These parts are all aluminum castings. In the upper body are the pressure gears, the driver being integral with the oil-pump shaft at whose upper ends is mounted a spiral gear which meshes with the large half engine speed gear. The idler pressure gear is bronze and it turns about a bolt which is used to tie the pump together. Oil enters the pressure pump through an opening in the plate and lower pump body. As it leaves the pressure pump, the oil must pass through a cylindrical screen of fine mesh which is held between the upper body and plate. Once through the screen, the oil can enter the drilled openings in the gear case which lead to the bearings or to the pressure relief valve.

Below the plate in the lower housing are the wider gears for scavenging. The driver is steel and it fits over a square on the drive shaft. The driven gear is bronze and it centers on the same tie bolt as the pressure driven gear above. Oil enters the cylindrical opening in the gear case surrounding the pump through the hollow dowel which is used to locate the gear case. It must pass through a coarse mesh brass screen before entering the gears.

The pressure and scavenging oil connections for the lines to the outside oil tank are alike. A hollow stud draws the bronze connection up against the lower body, a copper asbestos gasket being used above and below. These connections may be turned in any convenient position for the oil lines.

Excess oil from the pressure pump passes through a relief valve and re-enters the inlet side of the gears. The desired oil pressure may be obtained by screwing in or out the adjuster located at the lower rear of the lower pump body. The adjuster guides the relief valve, the latter being hollow to serve as a guide for the coil spring. The two oil connections, studs, the adjuster, as well as the two long screws which help to hold the three sections of the pump in a single unit are all made safe by lock wires.

Engine Support. LeBlond engines are supported by a welded steel mount *A*, Figs. 37 and 38. This consists of a ring of steel tubing to which are welded flanged clips for attaching to the crank-case studs. On the outer edge of the ring are welded four large triangular box section flanges, conveniently drilled for attachment to the airplane structure.

Inspection before Starting Engine. When the engine is installed in an airplane, the following items should be carefully checked before starting an engine. They need only be regarded, however, at frequent intervals, depending upon the amount of operation and the time elapsed between starts.

Make sure that the ground wires *B*, Fig. 38, are connected to the magnetos. Go over all nuts and bolts, both on the engine and engine mount, to be sure that they are tight and properly locked. See that the propeller is in balance and tracks within $\frac{1}{8}$ inch before installing.

Draw up the propeller hub nut as tightly as possible with a bar at a radius of 3 feet. See that all propeller hub bolt nuts are tight and properly cottered.

Lubricate the valve gear, using a Zerk gun filled with a heavy grease. Fill the oil tank with a sufficient amount of oil of recommended grade and find out if all the lines are open. See that the tanks are filled with a proper grade of gasoline.

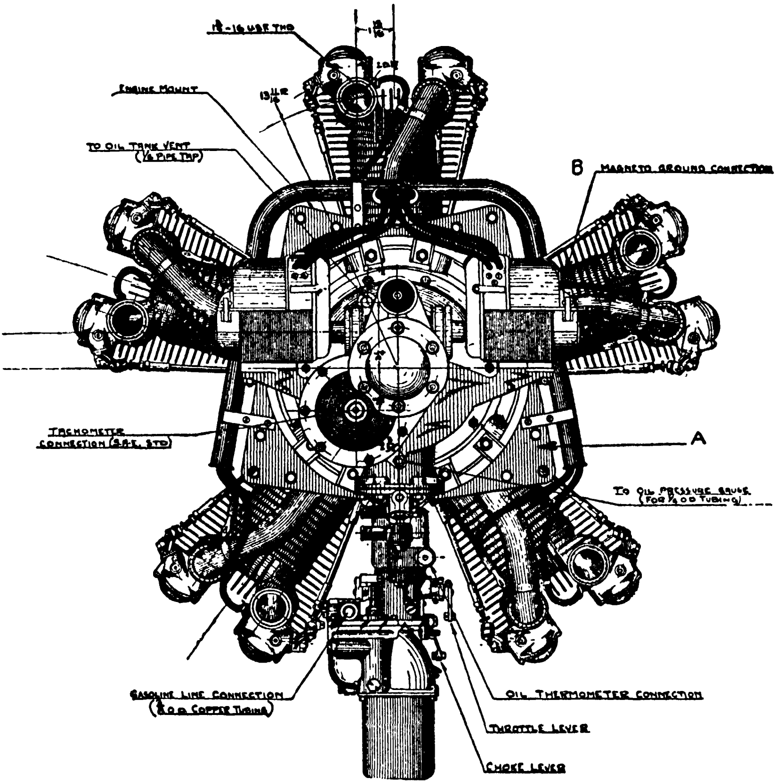

ENGINE MOUNT
TO OIL TANK VENT (⅛ PIPE TAP)
B
MAGNETO GROUND CONNECTION
TACHOMETER CONNECTION (S.A.E. STD)
A
TO OIL PRESSURE GAUGE (FOR ¼ O D TUBING)
GASOLINE LINE CONNECTION (⅜ O D COPPER TUBING)
OIL THERMOMETER CONNECTION
THROTTLE LEVER
CHOKE LEVER

Fig. 38. View of the LeBlond "60," Showing Control and Service Connections

Check the tachometer, oil pressure gauge, and oil temperature thermometer to see that each has been properly connected. Operate all engine controls to see if full and free movement is permitted. Inspect the carburetor, fuel, and oil lines to be sure that there are no leaks. Swing the propeller, with switches off, to make sure everything is clear.

Starting Instructions. The best method to use in starting will depend somewhat upon weather conditions. In cold weather it may be necessary to pre-heat the oil in order to get proper circulation at the start. In some instances it may help to prime the cylinders with gasoline through the exhaust port or through the spark-plug openings. Not too much gasoline should be used, however, as it washes the oil from the pistons and rings and invites scoring.

Under any condition, it is necessary to get sufficient gasoline in the carburetor so that some vapor may be sucked up into the manifold while turning the propeller by hand with switches off. If too much is drawn into the manifold, this can be relieved by turning the propeller in the opposite direction with the throttle wide open, again with the switches off. When the right amount of vapor has been drawn into the cylinders and manifold, the engine should start easily.

If the carburetor is equipped with an air heater, this should be on, especially in cold weather. Have the ignition switch in the off position. Close the throttle tight and, with the altitude control in the "full rich" position and the primer valve open, turn the engine over rapidly with the propeller, approximately three times. Close the primer and open the throttle to let excess gasoline drain out. Then, with the ignition switch on and the throttle in a slightly open position, the engine should start easily in one or two swings of the propeller.

LeBlond engines are equipped with fixed-spark magnetos set at 25 degrees advance position. It has been found that there is no appreciable increase in power with the spark set farther ahead and as this position makes it relatively safe from kick-backs with any manner of starting, the spark has been fixed in this position with the further advantage of eliminating the cumbersome control mechanism.

After the engine has started, it is best to open the throttle slowly until the tachometer reads 1200 revolutions per minute. Let the engine run at this speed for one or two minutes while observing if all plugs are firing and if the pump has picked up oil pressure. Should the oil gauge show no pressure at the end of one minute, the engine should be stopped and an investigation made as to the possible source of trouble. When the engine has run about two minutes and the oil pressure is 25 pounds or more, the throttle can then be opened up and the engine allowed to run until the oil temperature reaches 90 degrees Fahrenheit. In warm weather the oil may reach the required temperature in a short time while running the engine about 1500 revolutions per minute, while in extremely cold weather it may be necessary to bring the throttle to practically full open position.

When the engine has been properly warmed up, the throttle should be opened wide to observe revolutions per minute oil pressure and temperature. If the mixture control is connected, it should be adjusted to give maximum revolutions per minute. The magnetos can now be checked by switching from one to the other, and the speed should not drop over 75 revolutions per minute, as compared to both magnetos on. The acceleration of the engine with mixture control set at "full rich" position should also be checked to make sure it is smooth and rapid.

If everything appears normal and the operation is smooth, the engine is ready for flight. The mixture control lever should be placed in "full rich" position before taking off. It is recommended to always head the airplane into the wind while running the engine on the ground preparatory for flight. Prolonged running on the ground at full throttle may be harmful as the engine is not receiving the amount of blast which it requires for proper cooling.

Flying Instructions. When the desired altitude is obtained and the engine throttled down to cruising speed, the mixture control and air heater may be adjusted to positions giving the best fuel economy. The throttle should be set just ahead of the best cruising speed and the mixture leaned until this speed is obtained. The air heater may then be adjusted to best position for atmospheric conditions. In hot dry weather the heater valve may be left open; while in cold or moderate damp weather, it should be adjusted to give maximum revolutions per minute without formation of ice. Engine roughness at partial throttle is an indication of lack of heat. Once the best position of the heater valve is determined, it may be possible to further lean the carburetor mixture.

Frequent readings should be taken from the instruments to ascertain that the engine is functioning properly. The oil pressure should register between 40 and 60 pounds per square inch, although higher pressures are permissible; and at any time the pressure drops below 30 pounds, a landing should be made to determine the cause. The oil temperature should not exceed 180 degrees Fahrenheit, although it may go to 200 degrees in extremely hot weather before it is necessary to make a landing to investigate the cause—provided, of course, that the oil used meets with the recommendations. When using a fuel pump, the fuel pressure should range from 2 to 4 pounds per square inch.

Whenever the engine shows a greater variation than can usually occur through changes in atmospheric conditions, continued flight is not recommended. Trouble is evidently indicated and an immediate correction of whatever it may be will not only make for safety but it will save the engine from developing anything of a serious nature or undue wear.

Landing Instructions. The mixture control should always be set at "full rich" when the throttle is closed for landing in order to insure good engine acceleration in case it becomes necessary to again open the throttle. When the airplane comes to a final stop, after being taxied to its position, the engine should be allowed to run for a few minutes before shutting off the ignition. The recommended practice is to shut off the fuel supply and let the engine run until it has consumed all the fuel in the carburetor and feed lines. In this way the harmful effects of suddenly cooling off the engine can be avoided, lengthening the period of operation between engine overhauls.

KINNER AIRPLANE ENGINE

The Kinner Model "K-5" aircraft engine is of the fixed radial type with five cylinders. The bore is $4\frac{1}{4}$ inches and the stroke $5\frac{1}{4}$ inches. The total displacement is 372.5 cubic inches. The compression ratio is 5 to 1 and the weight dry, without propeller, is 260 pounds.

Cylinders. The cylinder is of a composite construction, having a finish machined-steel barrel with an aluminum-alloy head held on by ten studs and nuts. The valve seats are of special bronze, shrunk and spun into the cylinder head. The valve guides are also of special bronze.

The spark plug bushings are shrunk and screwed into the head and pinned to prevent turning. The rocker arm supports are cast integral with the head, the rocker arm pin being held in the rocker arm and floating in two bronze bushings pressed into the support. These bushings are flanged on the inside to provide bearings for side thrust. Lubrication is by Zerk fittings, a large supply of heavy oil being held by the hollow pin. The whole rocker-arm assembly is enclosed by a pressed steel cup held on by two cap screws.

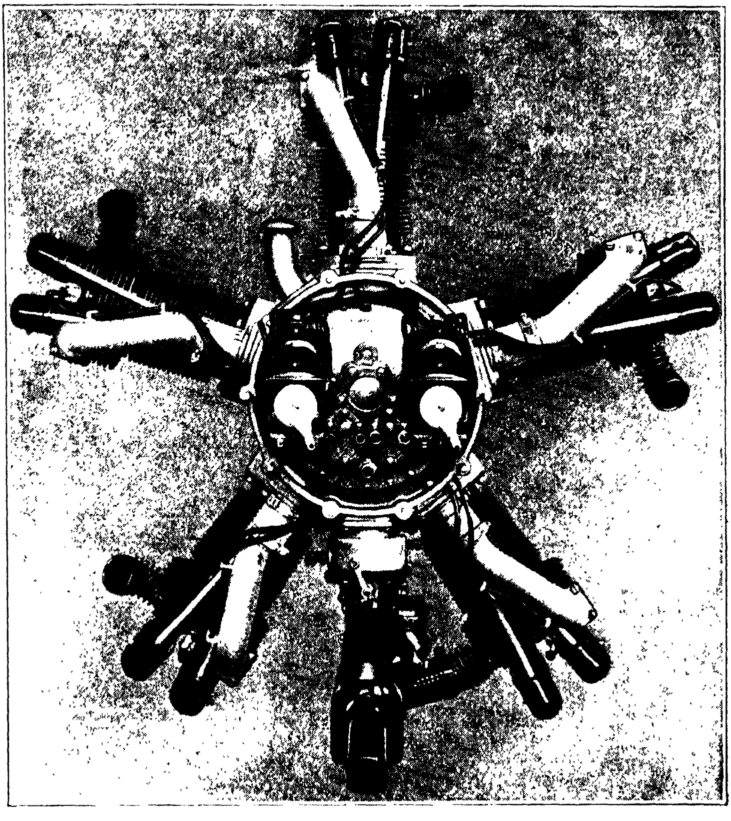


Fig. 39. Rear View of the Kinner 5-Cylinder 100-Horsepower Fixed Radial Air-Cooled Airplane Engine

Crank Case. The crank-case assembly is built up of three aluminum alloy castings held together by an adequate number of studs and nuts. The crank case is a single-piece casting and contains the cylinder pads, rear main bearing, camshafts and tappet assemblies, and the intake manifold cast integral with it. To the rear cover, Fig. 39, is fastened the oil pumps, magneto and starter adaption;

also the tachometer drive. The front cover contains the front main bearing and the deep groove radial ball-type thrust bearing. The front cover plate, Fig. 40, only aids in making an oil seal.

Crankshaft. The crankshaft is of the single-throw counterbalanced type, machined from a high strength heat-treated steel forging and finished all over. It is hollow throughout its length and is used to distribute oil to all parts of the engine. The crank cheeks are extended and counterweights attached to counteract all unbalanced dynamic forces. The crankshaft rides on two bearings, the front and rear plain bearings.

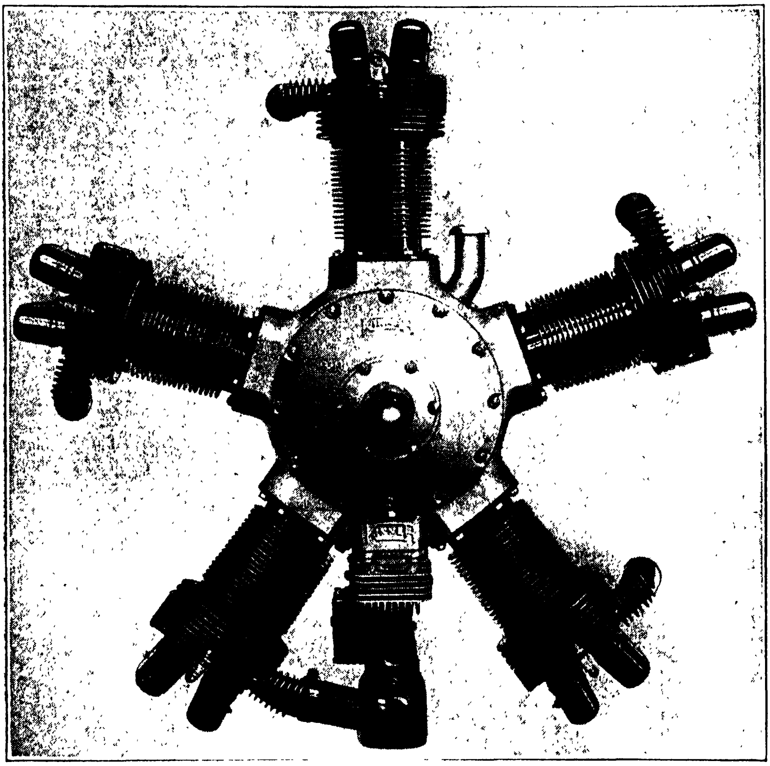


Fig. 40. Front View of the Kinner 5-Cylinder 100-Horsepower Fixed Radial Air-Cooled Airplane Engine

Valve Operating Mechanism. There are five separate camshafts located at the rear of the main crank case, driven at one-half engine speed from the main pinion gear on the rear of the crankshaft. The cam followers are of the roller type and run in aluminum alloy guides. Push rods are equipped with hardened ball ends with the tappet adjustment carried in the rear end of the rocker arm. The upper ends of the cam followers contain hardened steel sockets into which the lower push rod balls fit. The upper push rod balls fit into the hardened socket on the rocker arm.

Master Rod. The connecting rods consist of one master rod and four link rods machined from high-strength heat-treated steel forgings. The master rod is provided with a bronze-bushed babbitt-lined bearing, while the knuckle and wrist pin bushings of the link rods are of bronze.

Pistons and Wrist Pins. The pistons are of the conventional type and are of die-cast aluminum alloy. The inside of the head is ribbed to obtain strength and improve cooling. There are three compression rings and one oil control ring above the wrist pin. The wrist pins are machined from heat-treated alloy steel. Aluminum alloy plugs are used to prevent the pin from scoring the cylinder wall.

Valves and Valve Springs. The intake and the exhaust valves are of special heat-resisting steel. Both are of the tulip type with hollow stems and are interchangeable. The valve springs consist of two concentric helical coils of round steel wire per valve.

Ignition. Ignition is furnished by two Scintilla magnetos mounted on the rear of the crank case.

Carburetion. Carburetion is by a Stromberg "NAS-5A" carburetor. It is of the single-barrel type and is furnished with an air heater for cold weather. The manifold is cast integral with the crank case, and it is found very efficient at all engine speeds. The idling of the Kinner "K-5" is very smooth and acceleration good even after long glides from high altitudes with the motor off.

Lubrication. The lubrication system is of the pressure type except for the cylinder walls, wrist pins, and cam and accessory drive gears, which are lubricated by splash. Oil is carried with an external tank, not furnished with the engine. The oil is drawn from the bottom of the tank by the pressure pump and delivered to the various parts. Holes through the connecting-rod bearing shell convey oil to the knuckle-pin bearings. The various gears, shafts, etc., in the rear case are lubricated by spray from the main bearing.

Cylinders, pistons, and pins are lubricated by spray from the crankpin bearing. An oil thrower on the front of the crankshaft returns the oil from the front main bearing to the sump. Rocker arms are lubricated by Alemite Zerk fittings.

Accessories. The crank-case rear cover is fastened to the main crank case by twelve studs and nuts. It contains the oil pumps, oil pressure relief valves, tachometer drive, magnetos, Heywood starter mounting flange, and rear bearings of camshafts. Adaption is made for the Heywood air starter. The engine is started direct from the cockpit by operating a small valve. This eliminates the necessity of turning the propeller by hand.

Mounting. Do not attempt to even partially rest the weight of the engine on the magnetos or rocker-arm supports. The use of two horses and pads underneath opposing cylinders is the best method for supporting the engine while working on mounting. The mounting ring is preferably one inch or 1⅛ inch by 16 gauge tubing, bushed in conventional engine mount design. Care must be taken to see that the ring is not warped, as this would put undue strain on some bolts and may result in trouble, due to concentrated localized loading of the crank case. Leather or fiber washers are sometimes used between the ring and the case in mounting.

Wiring and Oil Lines. The motors are fully wired and need not be disturbed to mount the engine. Wiring of control switches for the magnetos must be done locally. Care should be taken to use proper size wire and that the screw in the ground connection makes contact with the wire or trouble will be experienced. Standard ignition cable or the equivalent copper size is adequate for control switches and ground wire.

The Kinner "K-5" is shipped with the necessary oil lines other than the main suction line, the return lines from scavenger and by-pass, and the gauge line. When possible, it is recommended that the oil tank be placed below the oil-pump level in the cowling. When so placed, a check valve should be installed in the suction line to enable the pump to always keep its prime. This check valve should be of such size as not to interfere with the free flowing of the oil by restricting the line. The suction line should be not less than one-half inch in diameter. A small line can be run from the tee in the pressure line to the oil gauge.

Looking at the engine from the rear, Fig. 39, the right-hand pump is the pressure pump and the left-hand one is the scavenger pump. The right-hand connection on each is the suction line and the left-hand one is the pressure line of the pressure pump and the return line of the scavenger pump.

Ordinarily it will not be necessary to install an oil cooler on Kinner engines, as the heat will be dissipated from the lines and tank. Under certain conditions, however, a cooler may be necessary, in which case it should be inserted on the return line from the scavenger pump.

Cowling. In the cowling of an air-cooled engine, extreme care should be taken to see that the proper ventilation and cooling are obtained by the engine. In cold weather some method of regulating this cooling is desirable. The crank case, lower halves of cylinder barrels, and carburetor should be enclosed to lessen the dangers of congealed oil. It is also advisable to lag all external oil lines with insulating material, such as asbestos. In warm weather this lagging must be removed.

Fuel System. No fuel pump is furnished with the Kinner "K-5" as the majority of planes equipped with this engine use gravity feed, usually from a center section tank, assuring a good head. The fuel line should be of $\frac{3}{8}$-inch copper tubing, heated and quenched after bending. A minimum head of 20 inches is required. On some planes, especially of low wing design, a wobble pump for pumping the gas from the main tank to a higher reserve tank is necessary to obtain the proper head for take off and climbing.

Carburetor. This is a "NAS-5A" Stromberg. The carburetor is adjusted at the factory to give the proper fuel consumption when mounted on the engine with no air scoop. If an air scoop is added, the fuel characteristics will be changed and a further adjustment necessary. It is recommended that the carburetor installation be left as set. The throttle and auxiliary air controls should be checked over to see that they are set to open and close properly. All connections to the controls should be made safe.

Gasoline Connections. All gasoline connections of the carburetors, gasoline tanks, etc., should be made with short sections of gasoline resisting fabric. The gasoline piping should be of such size that it will enter into the various connections in order that there will be no direct contact between the gasoline and rubber hose. Care should be taken to eliminate all kinks in the gas line that might cause vapor lock.

Magneto Wiring. The connection on the rear of the magnetos should be connected to the points of the grounding switch, marked "R Mag." and "L Mag." with insulated wire. The point marked "Grd." on the switch should be connected to the engine crank case. A booster magneto can be installed in the cockpit, in which case the high-tension lead will be connected to the terminal marked "H" on the right-hand side of the magneto. The body of the booster magneto should be grounded to the engine. If no starter is used, the booster will help considerably, especially in cold weather.

Starter. The Kinner "K-5" is equipped with a mounting plate to accommodate the Heywood air starter. The light weight, reliability, and ease of starting recommended this starter for the low horsepower engine. The starter should not be installed on the engine until the engine is installed in the mounting to which it is intended, as some of the lines may be cut too short.

Tachometer Drive Connection. The tachometer drive connection will be found on the rear cover between the magnetos. This is a standard U.S. Air Corps form with $\frac{7}{8}''$—18 thread. It rotates at one-half crankshaft speed in a clockwise direction as viewed from the open end.

Starting. Set the spark lever in the full advance position. Set the throttle in fully closed position. The small lever regulating the idling mixture should be set on rich with the altitude control also on rich. See that the magneto switch is in off position. Turn motor over slowly several revolutions. Throw magneto switch on "on" position and, with magneto fully advanced, crank the motor. After a few trials the best location of the propeller will be found for the individual who is cranking the motor. The motor should start easily on the first few revolutions. Immediately upon starting, note the tachometer reading and oil pressure. At 1000 revolutions per minute, the oil pressure should be 120 pounds with motor cold. Oil pressure is never to drop lower than 80 pounds per square inch at 1720 revolutions per minute with motor hot.

The normal engine speed is 1720 revolutions per minute, but the speed which the engine turns up on the ground depends entirely upon the design of the propeller with which it is fitted. In average weather two or three minutes at approximately 1000 revolutions per minute, is sufficient time to warm up the engine for take-off. Do not wait until the oil pressure drops, as this would take considerable time, and much harm can be done to the engine by running too long on the ground, as cooling is furnished mainly by travel through the air. For winter use, consult the oil chart.

Caution. Do not hold the motor wide open more than thirty seconds on the ground. The oil pressure is set at the factory and should not need changing if the proper grade of oil is used.

Regulating Oil Pressure. A noticeably lower oil pressure probably means a leak in the pressure lines somewhere, and an investigation should be made before readjusting the relief valve. Make sure that the pressure gauge registers correctly before making any changes in the oil pressure. The pressure regulating valve is located on the rear cover directly below the oil pumps. Loosen the lock nut and turn to the right to increase the pressure, and to the left to lessen the pressure. This regulator is very sensitive and only a part of a turn is necessary to change the pressure to the desired amount.

Care of Engine. After each flight or after each day's flying, a general inspection should be made. The engine should be thoroughly washed and the rocker arms and ball end of the push rods oiled. A very heavy oil, such as 600-W, or oil of like consistency should be used. The valve stem may be lubricated with either light engine oil or kerosene to loosen the dirt and gummy deposits on them. All valve adjustments should be made with the engine cold. In order to insure the best service from the engine, the following schedule of inspections should be maintained. Serious troubles very often come from minor causes which a few minutes inspection will eliminate.

Daily Inspection. Check all cylinders, one at a time, in firing order 1, 3, 5, 2, 4, as follows:

1. Tappet clearance between rocker arm and valve stem, .010″ cold, both intake and exhaust.
2. Are rocker arms free on shaft and properly locked in?
3. Are valves free in guides?
4. Are valve springs, washers, and lock nuts intact and nuts properly cotter keyed?
5. Are spark plugs tight?

6. Grease rocker arms using 600-W, or oil of like consistency. Remove push rods, examine and grease ball ends and sockets.
7. Are ignition terminals secure to wires and plugs and is insulation on wires intact?
8. Is compression normal and same on all cylinders?
9. Are carburetor and manifolds tight at securing flanges?
10. Are fuel tanks full?
11. Is oil supply filled?
12. Are magneto ground wires secure?
13. Are throttle, altitude, and magneto controls free throughout their range?
14. Is full throttle r.p.m. normal?
15. Is engine operation good on either magneto?
16. Is oil pressure and temperature normal?

Low Compression on One or More Cylinders. It is suggested that the compression be checked very carefully on each cylinder. As soon as one is found low, it should be removed, the valves tested for leakage, and the piston rings inspected. The valves should be ground and the piston rings replaced if necessary. In this way the engine can be kept up to power and speed.

Engine Trouble. Determining the cause of engine trouble is often complicated by the number of sources to which a given symptom may be attributed. The best method of "shooting trouble" is to decide first on the most probable causes, and then eliminate them one by one. Following are some of the most common troubles and their causes.

A. If the engine fails to start, it may be due to any of the following causes:

1. **Lack of fuel.** Examine fuel supply, shut off cocks, strainers, hose connections, and line for possible gas leak.
2. **Under or over priming.** See instructions on starting.
3. **Defective ignition wire and switch.** Examine the ignition wires for breaks or wear and improper connections. Sometimes trouble can be traced to a cheap or faulty switch.
4. **Spark plugs.** This includes dirty and broken plugs as well as those which have been in use and have badly burned electrodes. Much starting trouble is traced to the operator trying to use spark plugs too long without replacement. Set B.G. gap at .015″ and A.C. at .020″ to .025″.
5. **Incorrect tappet clearance.** Check the valve tappet clearance. This should be .010″ on both exhaust and intake when cold.
6. **Incorrect timing.** Check the valve and ignition timing.
7. **Water in carburetor.** Remove the plug from bottom of carburetor and flush out by turning on gas.

8. **Cold oil.** If the oil is too cold and heavy, it will be necessary to heat the oil before starting.

9. **Magneto breaker points.** See that the magneto points are clean and have proper gap (.012″). Test spark delivered by magneto.

10. Examine the engine for unusual conditions, turning over slowly by hand. Compression should be equal in all cylinders.

B. Low oil pressure, or none at all, may be caused by any of the following:

1. **Lack of priming.** Disconnect the oil suction line and fill pump with oil. Turn engine over while putting in the oil until the oil is sucked into the pump. Check the oil supply.

2. **Leak in suction line.** Examine the line and all connections for leaks or restrictions.

3. **Oil pressure relief valve.** Examine for proper seating and spring breakage.

4. **Crankshaft plug out.** This may be examined by removing the front cover.

5. **Excessive bearing clearance.** A bearing may be worn enough to cut down the pressure, in which case an overhaul is necessary.

6. **Worn oil pump gears.** This is only in case where the engine has been in use several hundred hours. With clean oil, the wear at any time is very small. The shaft through the oil pump body should not have over .003″ clearance.

C. Crank case fills with oil. This is usually due to the scavenger pump failing to function. The scavenger pump is kept primed by a size 55 hole or bleeder between the two pumps through the main body. Should this hole become stopped up by dirt or a piece of rubber from the hose, the scavenger pump would fail to work. This may be cleaned by taking the cover off of the pressure pump and running a piece of wire through the hole. The strainer in the oil sump on the base of the engine should be cleaned every fifty hours of running. Check the line from the scavenger pump to the sump for loose connections.

D. Engine runs unevenly. The full throttle speed of the engine will vary from 50 to 75 r.p.m. under different atmospheric conditions. It will also vary considerably with the condition of the propeller. Low power and uneven running may be traced to any of the following:

1. **Lean or rich mixture.** Make sure the altitude control lever is in the right position.

2. **Leaks in the induction system.** Examine the intake manifolds and pipes for leaks or cracks. This includes the hose which joins the pipe and flanges, carburetor and intake pipe gaskets.

3. **Spark plugs.** See that all plugs are clean and have proper gap.

4. **Valve and valve gear.** Check the valve tappet clearance, springs, washers, rocker arms, and push rods. Make sure the push rods are not rubbing the cylinder fins. See that the valves are not sticking.

5. **Poor grade fuel may cause 100 or more loss of r.p.m.** Make sure the gasoline is a good grade of aviation gasoline and that it flows freely to the carburetor.

6. **Magneto breaker points.** See that the magneto breaker points are clean and have the proper gap (.012").

7. **Overheating.** This may be caused by any of the above mentioned causes. It is easily recognized by the fact that the engine will run at normal speed just after idling and slowly falls off. Continued running of the engine exhibiting this symptom is liable to cause serious trouble. Other causes of heating are excessive oil, temperature, thin oil, insufficient oil pressure and quantity of oil, insufficient oil cooling, and improper cowling.

E. **Excessive oil temperature.** This may be caused by the following:

1. **Insufficient oil cooling.**
2. **Insufficient oil supply.** There should be at least three gallons.
3. **Low grade oil.** See that the oil is up to specifications.
4. **Scavenger pump fails to scavenge oil properly from crank case.**
5. **Low oil pressure.** Never below 80 pounds hot.

F. **Carburetor Leaking.** Due to the fire hazard, the engine should not run if carburetor leaks excessively. This may be caused by:

1. Leaky float.
2. Stuck float.
3. Poor seating of the needle valve.
4. Wear of the float fulcrum pin.

The carburetor should be removed and checked. If the float is leaking, the gasoline should be removed and the hole soldered. The needle valve seat should be removed, the valve lapped in with fine compound, and the assembly tested for tightness and float level.

DISASSEMBLING THE ENGINE

Overhaul. The length of time the Kinner "K-5" can be run without an overhaul cannot be set by the factory. This is entirely dependent upon the operator and the conditions under which it is run. Experience has shown that regardless of the condition of the engine, it should be completely torn down and cleaned every 200 hours. This is required by the tendency of the lubrication system to fill up with sludge. This is composed of gums formed by the oil and lint and substances taken into the engine through the carburetor and breathers. After 200 hours of service, the accumulation is likely to become enough to plug up one of the passages, resulting in serious trouble. The Welsh plugs in the crankshaft should be taken out, the inside of the shaft thoroughly cleaned, and new Welsh plugs installed. Do not try to use the old plugs, as the pressure when the oil is cold is sometimes very high and a leak would cause trouble.

Inspection. After removal of the engine from the ship, a tilting stand should be used for disassembly and assembly. There are several companies who specialize in stands of this kind or one can be made without much expense. If a stand is not available, it may be best to leave the engine bolted to the motor mounting in the plane.

Disassemble the engine in accordance with the following instructions. Wash each part in gasoline and place it on the inspection bench. This bench should be located in a clean place with plenty of light. A service kit is furnished with each engine by the manufacturer. This contains sufficient tools for general servicing and should be carried in the plane for use in emergencies. For completely disassembling and reconditioning of the engine, a number of special tools are essential. For such tools it is recommended the operator get in touch with the service department of the factory.

Propeller Hub. To remove the propeller hub, remove the propeller hub nut lock and pull the hub with puller furnished with the engine. This is a standard O.X.-5 tool and can be procured at the fields. The propeller hub key is held in the shaft by 10-24 screw.

Cylinders and Master Rod. When an engine is to be given a complete tear-down, the following rule should be strictly adhered to: *No. 1 cylinder, which contains the master rod, should be removed last and installed first.* Failure to do this and lack of proper care will result in broken piston rings, broken pistons, and possible cylinder injury. When it is necessary to make an exception to the rule, the piston in No. 1 cylinder should be run halfway down the stroke and left there until the cylinder is replaced.

The push rods may be removed by compressing the valve springs by pressure on the rocker arm and lifting out the push rod. Remove all spark plugs and rotate the crankshaft until the piston of the cylinder to be removed, is approximately at top center. Remove the three screws holding the intake pipe to the cylinder. Remove the cylinder hold-down nuts and rock the cylinder from side to side to loosen, then remove it by pulling it straight off.

As soon as a cylinder is removed, the piston should be taken off the rod to avoid injury. This can be done by driving out the wrist pin. If the aluminum plug in the wrist pin is broken or battered, it should be replaced with a new one. These plugs should be a light tap fit in the end of the wrist pin. The valves can be taken from the cylinder by removing the nut on the end of the valve stem and removing the cotter pin near the top of the valve stem.

Front Cover. To remove the front cover, it is necessary to remove the front-cover plate, which is held on by six studs and nuts, and then remove the oil thrower. This oil thrower is a very light tap fit on the shaft and can be readily removed by prying in back of it. The front cover can then be removed by taking off the twelve nuts around its circumference and removing the oil pressure line. A puller should be used to remove this cover, the puller being bolted to the front cover-plate mounting, and force exerted on the crankshaft end. If no puller is available, the cover may be loosened by prying between its circumference and the case on opposite sides and then pulled straight off by hand. In any case, care should be taken to see that the crankshaft is not allowed to come forward as the valve timing in the rear of the case may be disturbed.

Connecting Rods. Cut all the lock wires and remove the cap screws holding the two halves of the master rod together. The lower half, including the two link rods, may be slipped out of either lower cylinder hole. If the crankshaft is to be removed, it is best to first remove it and then take out the upper half of the master rod, including the two upper link rods. If it is desired to remove the rod only, without disturbing the crankshaft, the top half of the master rod must be worked first from one side of the case to the other to get both link rods and master rod end in No. 1 cylinder hole, when the assembly may be slightly turned and slipped out of the front of the crank case.

Crankshaft. Do not under any circumstances remove the crankshaft counterweights. If this is found necessary, the assembly, including rods and pistons, should be returned to the factory for balancing. The crankshaft cannot be removed without first removing the rear cover and cam gears. When this is done, the crankshaft may be lifted out.

Rear Cover and Accessories. In removing the rear cover, the magneto wires need not be disturbed. The fiber blocks on the magneto should be removed and tied to one side. All oil lines should be removed and the twelve nuts on the cover circumference should be removed. The cover may then be loosened by tapping the magneto base slightly with a lead hammer, when it may be lifted off easily. The rear cover, magnetos and magneto drive shafts, gears, and oil pumps come off in one assembly. The cam shafts may then be taken out. The order in which they are removed should be noted.

Magnetos. The magnetos may be removed by taking out four cap screws, holding each magneto to the base. To remove the magneto drive shafts, the lock pin through the driving half of the coupling must be taken out and the coupling driven off the shaft. The key is then removed and the shaft pulled out of the rear cover toward the gear end. The gear is a press fit on the shaft and is also keyed.

Oil Pumps and By-Pass Valve. Remove the twelve cap screws holding the pump and covers, and the pump assembly may be lifted off. This by-pass valve is located directly between and below the oil pumps on the rear cover. By loosening the lock nut, this valve can be unscrewed, exposing the spring and ball.

Tappet Guides and Tappets. The tappet guides are of heat-treated aluminum alloy, held in place by two $\frac{5}{16}$ studs and nuts. If it is desired to remove any of these guides, the intake manifold and connecting hose on the corresponding cylinders must first be removed. Unscrew the two nuts and the guide may be easily pried loose and lifted out, by using two screwdrivers.

Replacing Worn Parts. The question of when a part should be replaced is one which cannot be decided by rule and must be left largely to the judgment of the inspector. If it is necessary to replace the master-rod bearing, it is very important that the reaming be done accurately, which necessitates the use of a special reaming fixture. If this is not available, the rod should be returned to the manufacturer for replacement of the part.

Front and rear main bearings can be procured direct from the factory, with only enough metal left for scraping. In replacing the main bearings, the case should be heated in boiling water, the old ones driven out, and the new ones pressed in while the case is still hot. They should then be locked in the same manner as the old ones with small screws furnished for this purpose.

Caution. Front and rear bearings must be very tight in the case and cover.

Grinding Valves. If their condition warrants it, the cylinder valve seat should be refaced, using a proper tool for this purpose, and the valves faced off in a grinder. They should be ground and tested for tightness with gasoline.

Replacement of Valve Guides. If the valve guides in a cylinder become worn, it is advisable to replace them with new parts. In this way the valves are held straight in their seats and loss of compression leaks and burned valves are avoided. The hole in the cylinder head should be accurately measured and should be .001″ to .002″ smaller than the guide to be installed. Usually standard guides can be used for replacement. If the hole is found to be less than .001″ smaller than the standard guide, oversize replacement guides will be necessary. Do not try to use guides of more than .002″ larger than the hole, as a tighter fit may break the cylinder casting. Ream the guides to give a clearance of .003″ over the intake stem diameter and .005″ over the exhaust valve stem clearance.

REASSEMBLING THE ENGINE

The successful operation of the engine is absolutely dependent on the attention to every detail in inspection and assembly. It should be remembered that the slightest neglect on the part of the inspector or mechanic may result in the failure of the engine and possible loss of life.

Cotter pins and wires should never be used the second time. Care to prevent dirt, dust, lock wires, nuts, washers, or other parts from falling inside the engine, should be used. These might work into the gears or oil lines, causing serious trouble. Before assembling in the engine, all parts should be thoroughly cleaned and made free from grit.

As the engine will turn over a number of times before the oil pump will start to furnish a regular supply of oil, all bearing surfaces should be coated with a good supply of engine oil before assembling.

All joints, such as a cylinder flange to crankcase, should be thoroughly cleaned, and preferably Murphy's oil soap used for a filler. This soap may be procured from the Phoenix Oil Company, Cleveland, Ohio. Any plugs which may have been removed from the crankshaft for cleaning purposes should be replaced and thoroughly locked.

Crank Case. After thoroughly cleaning with gasoline, bolt the case to the stand by at least four bolts.

Crankshaft. The crankshaft, with the main drive pinion bolted and keyed in place, should now be inserted in place in the crank case.

Connecting Rods. The two halves of the master rod, with the link rods attached, should be put in the case before the crankshaft to facilitate assembly. Before these are bolted together, the bearing halves should be covered with cylinder oil. Draw the four screws up evenly until tight and lock in pairs with a good grade of annealed wire in such a manner as will tend to tighten the bolts rather than loosen them.

The link rod pins in the master rod are of the automatic locking type. To remove a pin, press the plunger down flush with the surface of the pin and drive the pin out with the pin drift. In assembling this unit be sure that the plunger aligns with the hole and snaps into place when the pin is in place. In assembling the engine, the lock pin side of the master rod should be to the front of the engine.

Front Cover. The ball-thrust bearing should be properly installed on the crankshaft, thrust side out. The front cover may now be put on and bolted in place. Care should be taken to see that the crankshaft has .010″ to .014″ end play with the front cover bolted in place. This is imperative. The oil thrower and front cover plate may now be installed.

Cylinders. The cylinders may now be installed, starting with No. 1. Each piston should be put on only as the cylinder to which it belongs is installed. Otherwise piston rings or pistons may be broken. Use new gaskets on the intake manifolds, and shellac each one to eliminate air leaks. Insert the push rods, the exhaust tappet being the one nearest the cylinder. The tappet clearance should now be set at .010″ on each valve.

Valve Timing. In assembling the cam action, the No. 1 cam is the first one to install. With crankshaft turned so that No. 1 piston is on top dead center, the No. 1 mark in the main timing pinion will be opposite No. 1 cylinder. The No. 1 mark on the cam gear should mesh with the No. 1 mark on the main timing gear. Next install No. 2 cam, meshing No. 2 mark on the cam gear with No. 2 mark on the main timing pinion. The next to be installed is No. 4. Do this in the same manner as before. Then No. 3 and 5 in like manner.

The reason for not installing in rotation is on account of the gear spacing necessary. The two cams with the slotted shafts are the oil pump drive cams Nos. 3 and 4. No. 1 cam is the shortest of all five in length from the front cam to the gear. No. 2 is tapped for the tachometer drive shaft and No. 5 is a plain shaft with no connections or slots.

Rear Cover. This cover should be completely assembled with magnetos and magneto drive shafts in place and properly locked. The oil release valve and oil pumps may be left off until the cover is in place. Be sure the short pipe between the case and the rear cover which connects the oil by-pass is in place. This should be a tight slip fit in the cover and a light tap fit in the case. This is very important.

The cover can now be put in place and properly tightened and locked. The oil pump can now be installed. Hold the pumps in their proper place and rock the crankshaft back and forth to align the driving slots. A very thin gasket should be placed beneath the pump body and tracing paper gasket should be used between the pump cover and the body. This gasket material should not be more than .003″ thickness. It is very important that there should be no leaks in the pump connection at any place. The release valve should now be installed. Screw this in about nine turns. With cold oil, the gauge should register 120 pounds to start.

Magneto Timing. The magnetos should now be timed, preferably by the use of a timing disc. These should be set 30 degrees before top dead center on full advance. If no timing disc is available, set them with points just starting to break on full advance one-half inch in piston travel before top center.

To set magnetos, loosen the three screws on the magneto coupling and then turn the magneto shaft until the segment on the rotor is opposite the No. 1 segment in the block with the points just breaking on full advance, engine set on top dead center. When properly set, tighten the flange nuts and recheck to make sure the flange has not slipped while tightening. The two magnetos should be as nearly synchronized as possible. This may be checked by placing a thin piece of paper between each set of points and turning the engine over slowly by hand. The paper should be released simultaneously by each set of points.

Priming Oil Pump. After the engine is installed in the ship and all oil lines are connected, loosen the pressure line at the T where the gauge line connects in and prime the pump by pouring oil in this pipe while turning the engine over backward until the pump has sucked in about a cupful of oil. The scavenger pump will prime itself from the pressure pump as soon as the engine starts.

WARNER "SCARAB" AIRPLANE ENGINE

The "Scarab," Fig. 41, is a 7-cylinder radial air-cooled aviation engine. The cylinder bore and stroke is $4\frac{1}{4}$ inches. Its rated power is 110 horsepower at 1850 revolutions per minute. Due to the fact that all accessories are located in the rear, the engine offers a clean appearance and can very readily be cowled in. All accessories are arranged in such a way that the time required for installation is cut to a minimum.

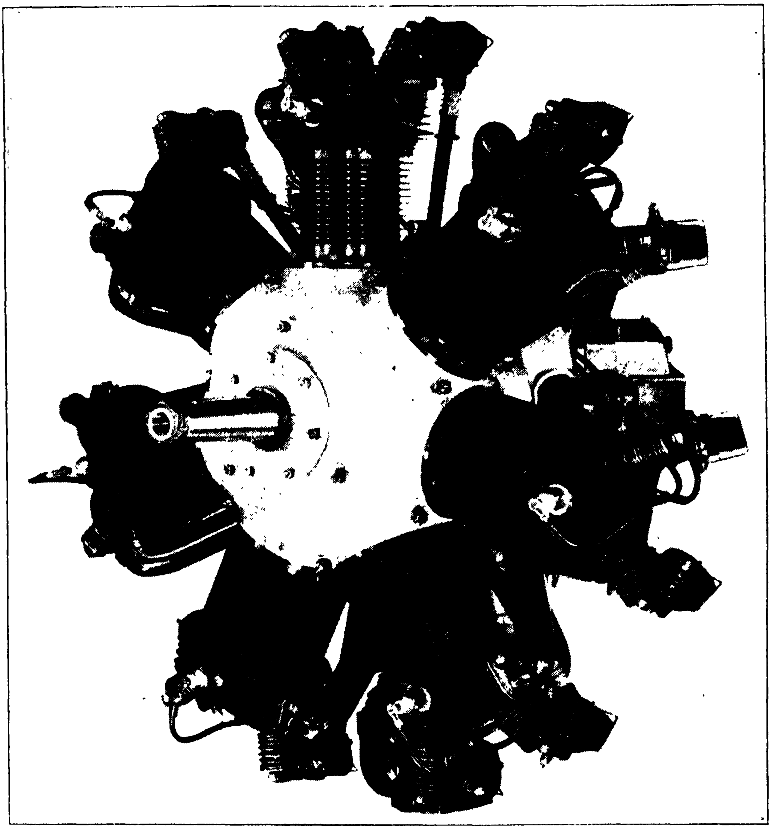


Fig. 41. Front View of 110-Horsepower Warner "Scarab" Aircraft Engine
Courtesy of Warner Aircraft Corporation, Detroit, Michigan

In this treatise the propeller end of the engine is referred to as the front end and the anti-propeller end is referred to as the rear end. Right and left sides of the engine are designated as viewed from the rear end. The rotation of the crankshaft is clockwise when viewed from the rear end. The cylinders are numbered from 1 to 7 in direction of rotation, beginning with No. 1 at the top. The push rods and cam followers are marked alphabetically in the direction of rotation, starting with the exhaust side of cylinder No. 1.

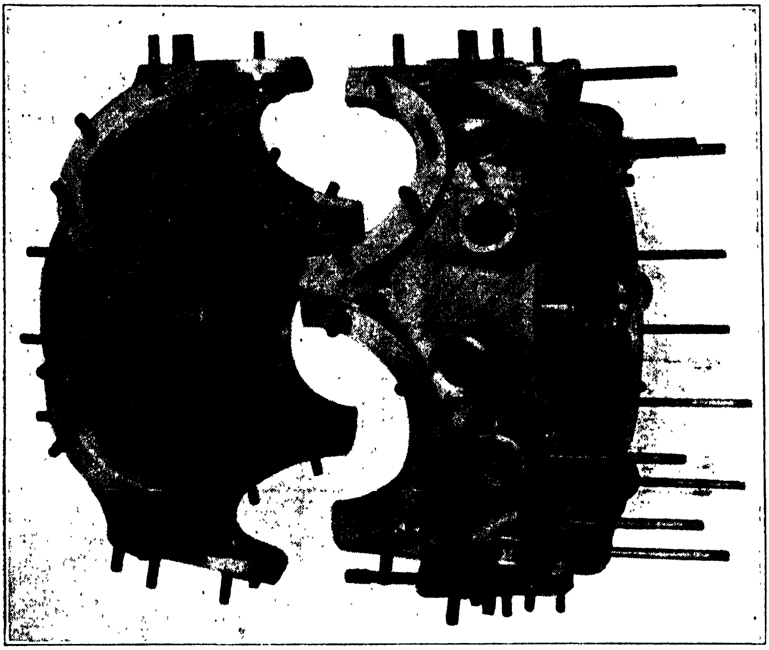


Fig. 42. Crank Case of Warner "Scarab" Engine
Courtesy of Warner Aircraft Corporation, Detroit, Michigan

Crank Case. The crank case, Fig. 42, is made up of two heavily ribbed halves, which are parted at the center plane of the cylinders and are held together by means of bolts between the cylinders as well as by the cylinder flanges. This construction facilitates the assembling of the crankshaft and the connecting rods as a unit. Each half carries one main bearing; the front half, in addition, supports the propeller thrust bearing.

Induction System. To the rear of the crank case is bolted the induction housing to which at its lowest point the oil sump is attached, the carburetor in turn being attached to the oil sump. The fuel mixture flows from the carburetor through a circular passage in the induction housing and thence through cast-aluminum intake pipes to each cylinder. Bronze bearing bushings are pressed into the induction housing for the idler shaft, auxiliaries drive shaft, and tachometer drive shaft. There are ten lugs on its outer circumference, which are drilled to accommodate ten $\frac{5}{16}$-inch diameter bolts for mounting the engine on the fuselage.

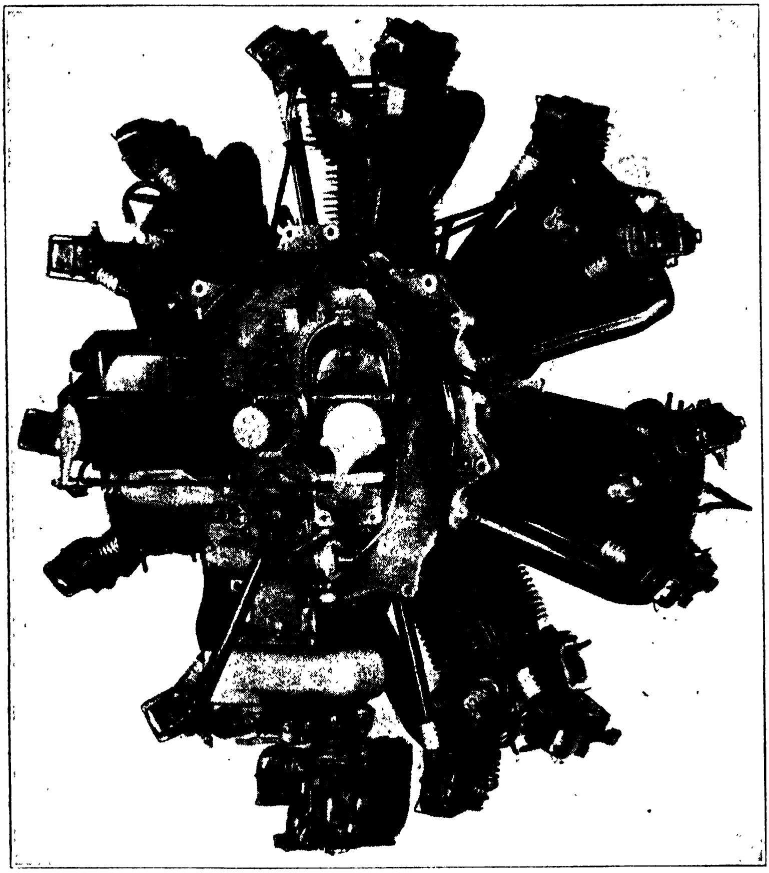


Fig. 43. Rear View of 110-Horsepower Warner "Scarab" Aircraft Engine
Courtesy of Warner Aircraft Corporation, Detroit, Michigan

Gear Case. The gear case is attached to the rear face of the induction housing, Fig. 43, and carries the accessories and their drives, including two Scintilla magnetos, oil pump assembly, an oil strainer, and an oil pressure relief valve. The starting clutch is located between the two magnetos and is protected by a cover. To use a hand or electric starter, this cover must be replaced by a starter adapter, which may be obtained from the factory.

Crankshaft. The single-throw counterbalanced crankshaft, Fig. 44, is fitted with three ball bearings. It is made from an alloy-steel forging, carefully heat-treated and finished allover. The rear end of the shaft is connected with the accessories drive shaft by means of a flexible coupling. This accessories drive shaft drives the magnetos, oil pumps, and cam gear; and it is fitted at the end with a 6-spline standard starting clutch. The propeller end of the crankshaft is machined to S.A.E. specifications No. 1, for shaft ends.

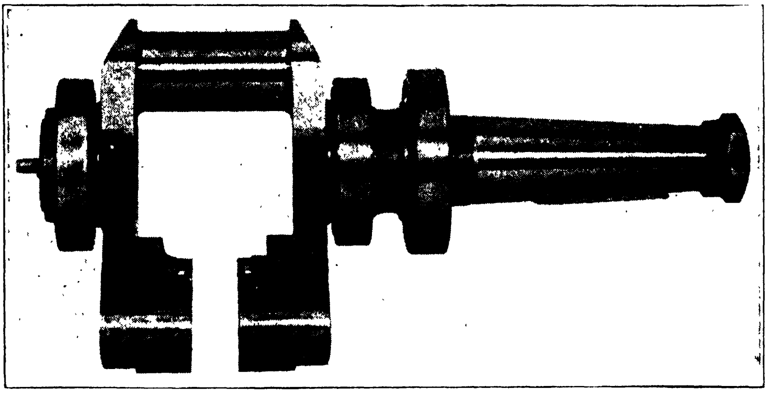


Fig. 44. Crankshaft of Warner "Scarab" Aircraft Engine
Courtesy of Warner Aircraft Corporation, Detroit, Michigan

Connecting Rods. The master and link rods, Fig. 45, are of I-section design, smoothly machined on all surfaces from carefully heat-treated alloy-steel drop forgings. The master connecting rod is of the split type, the cap being attached by means of four bolts. The bore for the crank pin is babbitt lined. The link rods are assembled to the master rod by means of wrist pins, which are locked to the link rod and take their bearing in bronze bushings pressed into the master rod. Bronze bushings are also pressed into the piston pin end of all rods. Pressure lubrication is employed for the crank pin and all wrist pin bearings.

Pistons. Permanent mould aluminum pistons are used. Each one is fitted with two compression rings and one oil scraper ring. The piston pin is of the floating type with soft plugs pressed into the ends to prevent scoring of the cylinder walls.

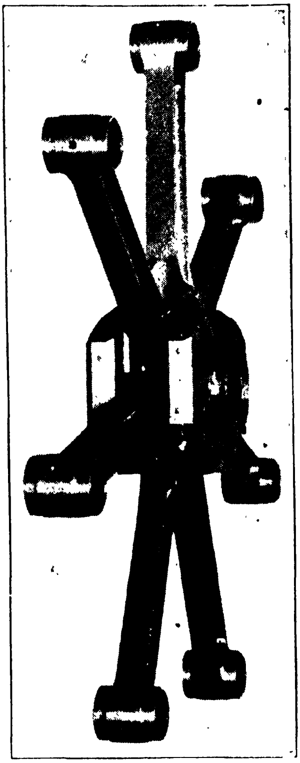


Fig. 45. Connecting-Rod Assembly of 110-Horsepower Warner "Scarab" Aircraft Engine
Courtesy of Warner Aircraft Corporation, Detroit, Michigan

Cylinders. The cylinder barrel is machined from an alloy-steel forging, shrunk and permanently bolted to the aluminum alloy head. Adequate fins on both the barrel and the head give a proper cooling capacity. Each cylinder is fitted with one intake and one exhaust valve. Valve guides and bronze valve seats are shrunk into the cylinder head. Each cylinder is provided with two 18MM-15MM pitch tapped holes for the spark plugs—one in the front and one in the rear.

Valve Mechanism. Both the intake and the exhaust valves are of the tulip type and are fitted with two valve springs each, which are exposed to the slip-stream for cooling purposes. The springs are interchangeable for the intake and exhaust valves and are securely fastened to the valve stem by means of a split cone and washer.

The rocker arms are made from alloy steel forgings and are supported in aluminum-alloy housings, which are bolted to the cylinder head. The front end of each rocker arm is equipped with a steel roller, which makes contact with the end of the valve stem. The rear end of each rocker arm is completely enclosed for protection and is fitted with an adjustable steel socket into which the ball-shaped hardened end of the push rod fits. The pressed-brass rocker-arm housing cover is held in place by a spring bail and can easily be removed for adjusting the valve clearance.

The cam ring operating the valve gear is made from an alloy-steel forging, casehardened on all wearing surfaces, and the bearing bore on which it rotates is lined with babbitt. It is located in the rear half of the crank case and operates the push rods through the cam followers, which run in permanent mould aluminum guides. Each push rod is enclosed in an aluminum tube.

Lubricating System. There is one pressure pump and one scavenger oil pump located below the starter clutch at the rear of the engine. The two pumps are arranged in tandem and are driven by one shaft, the scavenger pump being toward the rear. The oil is drawn from the oil tank by means of the pressure pump and from there it is forced through a strainer below the pump to the auxiliaries drive shaft and thence to the crankshaft. It passes through drilled passages to the crank-pin bearing and from there is forced into each wrist-pin bearing. The oil which is forced out of these bearings lubricates the remainder of the engine by splash and then collects in the oil sump, which is located between the induction housing and the carburetor. From there, the oil is returned to the oil tank by means of the scavenger pump.

STARTING AND OPERATION

Check the amount of gas in the tank. Use only domestic aviation gasoline. No low test or doped gasoline should be used except in case of an emergency. Check the amount of oil in the tank, which should be approximately 80 per cent full. In air temperatures above 40° F., use only pure paraffine-base oils of grade 2 or 4, according to U.S. Army specifications No. 2-23 F. In air temperatures below 40° F., a similar oil with a pour point of less than 10° F. should be used. The engine should at no time be operated with less than two gallons of oil in the tank. Oil the rocker-arm rollers by squirting a few drops of light engine oil on them.

Starting Engine. Prime, if the primer is installed in the ship, or hold a rag under the carburetor intake while the ignition switch is off and the propeller is being turned in the forward direction. The throttle should be cracked open for starting and the mixture control set to full rich. The spark control should be fully advanced if the starting is done by swinging the propeller, but it should be from fully retarded to one-third advanced if starting is effected by a hand or an electric starter. The ignition switch should always be set to "Both" when the engine is in operation. The L and R setting should be employed only for checking the ignition systems. A loss of approximately 30 to 40 revolutions per minute will be found when the engine is running on one magneto only with full open throttle.

Warning. After the engine is started, do not allow it to run at a speed greater than 800 revolutions per minute until the oil thermometer registers the temperature range usually observed on the ship. The engine should not be operated at or close to full power with an oil temperature in the engine below 100° F. or 40° C. The thermometer will indicate a different temperature, according to the installation of the thermometer and the amount of oil carried, the difference to be determined by experience on the various installations.

Flying. When flying, the spark-control lever should be set to full advance. After taking off, the throttle control should be set to obtain the desired cruising speed of the engine and then the mixture control should be set to the point where the highest revolutions per minute is obtained for the chosen throttle setting. Care should be taken not to lean out the mixture too much as it is apt to cause rough operation and heating up of the engine. When landing, set the mixture control to "full rich" to prevent stalling of the engine when reaching lower altitudes.

Caution. Stop the engine at once if, in starting, the oil pressure gauge fails to indicate pressure a short time after starting or if the oil pressure drops in the running engine below the value usually observed at the temperature range. With increasing oil temperatures, reduced oil pressures will be observed.

WARNER "SCARAB" ENGINE

General Specifications

Type	Static—Radial—Air-Cooled
Number of cylinders	7
Cycles	4
Bore	4¼ inches
Stroke	4¼ inches
Piston displacement	422 cu. in.
Compression ratio	5.2:1
Normal speed	1850 r.p.m.
Rated power at 1850 r.p.m.	110 hp.
Direction of rotation of crankshaft (looking at propeller end)	Anti-clockwise
Tachometer shaft speed	½ crankshaft
Rotation of tachometer shaft (looking from the rear)	Anti-clockwise
Weight dry without hub or starter	275 lbs.
Specific weight	2.5 lbs. per rated hp.
Ignition	Dual Scintilla MN-7—D clockwise
Magneto timing (full advanced)	32° B.T.C.
Magneto breaker gap	.012 inch
Carburetion	Stromberg single barrel 2-inch carburetor
Spark plugs	A.C. Aviation (18MM—1.5MM pitch thread)
Spark-plug gap	.021 inch
Guaranteed fuel consumption at rated power	.55 lbs. per hp. hour

Guaranteed oil consumption at rated power	.025 lbs. per hp. hour
Valve tappet clearance when cold	.010 inch
Valve tappet clearance when timing	.027 inch
Valve timing (at .027 tappet):	
Inlet opens	10° B.T.C.
Inlet closes	60° A.B.C.
Exhaust opens	60° B.B.C.
Exhaust closes	10° A.T.C.

WARNER "SCARAB" ENGINE

Installation Dimensions

Overall length without starter	29 inches
Overall diameter	
1928 Series	$35\frac{1}{2}$ inches
1929 Series	$36\frac{1}{4}$ inches
Distance from mounting to C.L. of Cylinders	$6\frac{29}{32}$ inches
Distance from mounting to rearmost point	$9\frac{19}{32}$ inches
Diameter of mounting bolt circle	17 inches
Mounting bolts (not furnished)	$10\frac{5}{16}$ inches S.A.E.
Oil lines to tank (not furnished)	$\frac{5}{8}$-inch O.D. tubing
Gasoline lines (not furnished)	$\frac{5}{16}$ inch or $\frac{3}{8}$ inch O.D. tubing

Propeller Flutter. If propeller flutter is experienced, it probably is due to a loose propeller. Tighten the hub to the shaft and, if it is a metal propeller, inspect the blade clamping bolts and at the same time check the setting of the blades. If a wooden propeller is used, tighten the propeller attaching bolts evenly and check the track of the blades after doing so.

Periodic Inspection after Every Five Hours of Flying. Grease the rocker-arm shafts by means of the grease gun, with plain cup grease of good quality. On engines with plain bearing rocker arms, grease the ball end of the push rods, after removing the rocker arm housing cover, with a mixture of grease and graphite or preferably with Dixon's No. 677 graphite grease. Press down on the roller end of the rocker arm to open the valves; then fill the ball socket on the other end of the rocker arm with the lubricant, either from below or from the top through the hole in the socket. This may be done with a grease gun. On engines with ball-bearing rocker arms, the push-rod ball end is greased simultaneously with the rocker-arm bearing through the Alemite fitting and does not need special attention.

Check Tappet Clearance. The tappet clearance should be .010 inch for the intake and exhaust valves when the engine is cold. To check the clearance, turn the propeller forward until the intake valve on cylinder No. 1 closes, then turn the propeller an additional 120 degrees—one-third of a full turn—which brings the piston to top center. Insert the feelers between the valve stem and the rocker-arm roller for measuring. Make adjustment if the clearance is found to be below .010 inch or above .012 inch. When cylinder No. 1 has been adjusted, turn the propeller forward 120 degrees beyond the closing of the intake valve on cylinder No. 2, then check the clearance of this cylinder. Continue this procedure all around until all tappets are checked and adjusted. There are four cams on each cam-ring surface with four low base surfaces between them. If in checking cylinder No. 1 it should be found that the clearance is considerably more than that specified on both valves, it is advisable to turn the propeller exactly two full turns forward, which brings the next cam base into action. Check the tappet clearance again. By repeating this operation three times, the cam base having the least tappet clearance will be found, and this base should be used to check the clearance of the tappet on all other cylinders.

After Every Fifteen Hours of Flying. Drain the oil by opening the pet cock or plug at the bottom of the oil tank and by removing the drain plug at the bottom of the engine. The tank and the engine may be flushed with clean light oil if grit is found in the old oil. Remove the oil screen at the left side of the engine by unscrewing the acorn nut and pulling out the cover with the screen. Wash it in clean gasoline but do not replace it in the engine before it is completely dry. Fill the oil tank eighty per cent full with approximately four gallons of oil, after the screen and all the plugs have been replaced and have been secured with lockwire wherever provision is made for it.

Clean gasoline strainer, if one is installed, making sure not to trap any air in the strainer. Open the gasoline petcock and then close the strainer tightly after it has been observed that gasoline is leaking out of the strainer. Oil the magnetos, especially on the drive end, with a good grade of light engine oil; at the same time oil all the moving joints of the spark and the mixture and throttle controls.

Tighten all the nuts and bolts, immediately replacing cotter pins and lockwires when they have been removed for any purpose. Great care should be taken not to forget the propeller hub bolt nuts if a wood propeller is used, the thrust cover nuts behind the propeller hub, all the nuts in the rear of the engine, and the mounting bolt nuts. The intake pipes are made from aluminum, therefore the bolts or nuts holding them to the cylinders should not be tightened excessively as this will deform the flanges and cause leaks.

Check the throttle action and the mixture and spark controls, making sure that the full movement of the controls in the cockpit corresponds to the full movement of the controls at the engine. Adjustments may be necessary where wires and springs are used to make the control connections.

Check the ground wire and the switch wire connections at the engine and at the switch. It is very important to see that these connections are tight and that there are no breaks in the wires. This is to prevent accidental starting of the engine should the propeller be turned while the ship is standing on the ground with the ignition switch set to "off." Check all high tension wires to make sure that they are not being chafed anywhere by sharp edges.

Examine all spark plugs for cracks in the insulation. These are usually caused by rain. Wipe the insulation clean but do not remove the plugs unless there are indications that they are not functioning properly. Inspect the valve gear in regard to springs, rocker arms, etc. The rocker arms and the rollers at their ends must move freely and show no signs of sticking.

TOP OVERHAUL

By top overhaul is meant the grinding of valves and the making of necessary adjustments on the cylinders. If an engine has been properly taken care of, this should not be necessary before 100 to 150 hours of flying, and in some cases even less often. The need for a top overhaul is usually indicated by not being able to get the required engine speed on the ground with full-open throttle. It will be found that the propeller speed will vary with the air temperature and the barometric pressure; but a drop in speed of more than 100 revolutions per minute may be taken as an indication of the need of a top overhaul.

Before testing the ground speed for the purpose of determining the necessity of a top overhaul, make the following checks and adjustments. Be sure that the mixture control lever on the carburetor is in the "full-rich" position when the control lever in the cockpit is in the corresponding position. Check the spark advance lever on the magnetos in the same way. With the feeler gauge, check the magneto breaker gap, which should be .012 inches, and at the same time check the valve and magneto timing in accordance with instructions given under the section on "Complete Overhaul." Be sure that the fuel flow to the carburetor is not obstructed. If the oil pressure is below sixty pounds per square inch at 1800 revolutions per minute, inspect the relief valve to see that it is clean and free from burrs. Replace the valve spring with a new one if necessary. The relief valve is located in the rear of the engine, just below and to the right of the oil pump, and it can be screwed out after removing the lockwire.

Disassembling the Engine. A top overhaul can readily be made without dismounting the engine from the plane, with the tools found in the tool kit furnished with each engine. After removing the propeller, the cowling, and the exhaust pipes, clean the outside of the engine with gasoline.

Caution. On account of the fire hazard, do not attempt to wash the engine before it has been thoroughly cooled off.

Caution. During the following disassembling, be careful not to let dirt or washers, etc., fall into the engine, as this may cause serious damage.

If new gaskets are not available, be careful in removing the old ones, and immediately place them between two wooden covers to prevent their drying and cracking. Disconnect all ignition cables from the spark plugs and pull them through the rubber rings with which they are held to the push-rod tubes. In order to facilitate reassembling, it is advisable to tag and mark each cable as it is taken off the cylinder. Remove all spark plugs and rocker-box covers. Unscrew the two cap screws or nuts with which each intake pipe is attached to the cylinder and remove all intake pipes. The cylinders are detached by unscrewing the eight nuts nearest the crank-case pad, with tool No. FA-33. The two rear nuts are the most difficult to reach and should be removed first.

Caution. Under no circumstances should the nuts be removed at the joint between the cylinder barrel and the cylinder head, as this is a permanent joint.

Remove the cylinders, push rods, and push-rod tubes from the engine in numerical order, beginning with cylinder No. 1. The master rod is assembled into the cylinder. In performing this operation, great care must be taken that the pistons do not drop against the crank case and become marred or dented. As each cylinder is taken off, push out the piston pin immediately and remove the piston. All parts so dismantled from the engine should be laid on a clean bench in the order in which they are removed. While overhauling the cylinders, wrap a piece of cloth around the engine to protect it against dust and dirt.

On the earlier series of engines, the rocker arms should be removed next; but the rocker boxes should be left attached to the cylinders. Before removing the arms, they should be checked for play. Where this is found to be excessive, they should be replaced by new arms. The old arms may be returned to the factory for rebushing and reaming. On the later series, it is not necessary nor is it desirable to remove the rocker arms in order to grind the valves, and they should be taken apart only when some part is damaged or broken. It should be determined when valves are leaking and need grinding. This is done by pouring gasoline into the valve port.

To remove the valves which leak, place the cylinder over a smooth wooden block. This block should be $4\frac{1}{8}$ inches in diameter, 9 inches high, and rounded at its upper end so as to fit, approximately, the cylinder dome. It is best to have the block attached to a wooden base so that it stands upright on the work bench. This block serves to hold the valves closed while the springs are being removed. Depress the valve springs with tool No. FA-31. Remove the split cone, the valve washers, and the springs; then take off the circlet which is snapped into a groove in the valve stem. This circlet must be removed and assembled from the side and it should never be pulled over the end of the valve. To avoid damaging the valve guide when pulling out the valve, inspect the stem end for burrs. If any are found, they must be removed.

Reconditioning and Valve Grinding. After both valves have been removed, scrape off all carbon from the cylinder dome and from the valves, being careful not to mar or scratch the valve seats and the valve stem. The carbon should also be scraped off the top surface of the piston, which should afterwards be laid on a surface plate and smoothed with a piece of kerosene-soaked crocus cloth. Inspect the piston for cracks and check the piston pin for proper fit in both the piston and connecting rod. Check the piston rings for gap and side clearance in the grooves. If there are any sharp edges and scratches on the pistons or in the cylinder-wall surfaces, they should be carefully removed by stoning with a fine grade oil stone. Be sure all push-rod ball ends are tight on the rods.

To grind the valves, spread a small amount of grinding compound all around the seat of the valve, insert the valve in place, and grind with tool No. FA-29. Repeat this operation until a good seat is obtained, then wash the valves and cylinder carefully with gasoline so that no trace of grinding compound remains. A simple and handy fixture for holding the cylinder while grinding the valves or cutting the valve seats is a six- by twelve-inch steel plate, $\frac{3}{8}$ inches thick, with a $4\frac{1}{2}$-inch diameter hole near one end. The cylinder should be attached to this plate with two $\frac{5}{16}$-inch diameter bolts holding the cylinder flange to the plate; the other end of the plate should be clamped in a vise.

Assembling. Before assembling, be sure that all parts are absolutely clean and in good condition. As the parts are being put together, oil generously all bearing and other contact surfaces. Put the valves in place, being careful not to interchange those of different cylinders. The cylinder number is etched on each valve stem, just below the groove. Put the cylinder over the wood block used for disassembling, snap the circlets into their grooves, and assemble the lower valve spring washer, the springs, and the upper washer to the head. Depress the springs with a tool and assemble the two halves of the split-cone retainer. Be sure that the two halves used on each valve bear the same number.

After the valves have been so assembled, they must be inspected with gasoline for tightness; and if they are still leaking, the entire procedure must be repeated until they are tight. After the valves are tight, assemble the rocker arms in cases where they have been removed. The cylinders are now ready to be replaced on the engine. Inspect all crank-case pads for burrs and place the cylinder gaskets on the pad. On each piston, starting with piston No. 1, space the piston-ring gaps 120 degrees apart, assemble the piston with the number stamped on the top surface toward the propeller end, and push the piston pin in place, with all the marked ends in the same direction.

Before attempting to assemble the push-rod tubes and push rods to the engine, turn the crankshaft so that both cam followers are in their bottom position. After the entire piston has been oiled generously, clamp tool No. FA-46 over the piston rings. Put a new packing on each end of the push-rod tubes if necessary and, in addition, there must be a cable ring on each tube of cylinder No. 1. On the 1929 series of engine, assemble a steel washer between the packing and the shoulder on the inner end of the tube. On the outer end, assemble the spring, the washer, and the packing, in the order mentioned. The push rods are placed into the tubes with the marking toward the rocker arm. The rods are marked alphabetically, starting with A for the exhaust side of cylinder No. 1 and following around the engine clockwise when viewed from the rear.

The cylinder, with its wall generously oiled, is then slipped over the piston. As soon as the rings are inside the cylinder, the clamping tool must be removed; and, as the cylinder is pushed further in, great care must be taken in guiding the push rods and tubes into the rocker boxes. Be sure that the spring ball for the rocker-box cover is outside the push-rod tubes. After the cylinder is on, fasten it to the crank case with the eight nuts and lock washers. Draw these down evenly. After cylinder No. 1 has been assembled to the crank case, all the other cylinders must be assembled in numerical order in the same way. Note that on cylinder Nos. 2, 3, and 4, only the exhaust push-rod tubes require cable attaching rings; and on cylinders Nos. 5, 6, and 7, this ring is put on the intake push-rod tubes only.

If the engine has been in use for any length of time, new rubber packings should be used on the intake pipes every time one is removed, as the old packings may be difficult to assemble and will not hold tight. Dip the intake pipe gasket in castor oil to warrant a perfect seal and put it on the intake flange of the cylinder. Assemble the spring and gland, with the flat surface toward the spring, and the packing to the intake pipe; press the latter into the induction housing and fasten it to the cylinder.

Set all valve tappet clearances to .010 inch, following instructions given under "Periodic Inspection," and put on the rocker-box covers. Check the gap on all spark plugs. This should be .021 inch. Next screw the plugs in place. Make sure there are no burrs on the threads. If a plug does not screw freely into the head, it should not be used as it will damage the aluminum thread in the cylinders. Next replace all ignition cables. It is not necessary to time the valves or the ignition after a top overhaul.

COMPLETE OVERHAUL

When an engine has been in service 350 to 500 hours, and has been top overhauled once or twice, it should be completely overhauled. This will be needed after a still shorter period of service if the engine has been subjected to less care in maintenance and operation.

Disassembling the Engine. To disassemble an engine completely, it must first be removed from the plane. Block the wheels of the ship, then remove the cowling, the propeller, the exhaust pipes, and the carburetor heater, if one is installed, and disconnect the oil, gasoline, tachometer, and all gauge connections. Also remove the long oil line at the rear of the engine. Support the engine at the two lifting eyes back of the top cylinder by means of a pulley. Remove the ten $\frac{5}{16}$-inch diameter mounting bolts and hoist the engine from the plane, carefully clearing the magnetos and other accessories in the rear.

Place the engine on an assembly stand and attach it to the frame with from four to six bolts. Clean the outside of the engine thoroughly with gasoline before attempting to disassemble. All small parts should be placed between two wooden covers so as to prevent their drying and breaking. If any part cannot be freely removed, use a fiber drift in order not to damage the part.

Removing Auxiliaries. Take off the ignition cables by disconnecting the spark-plug terminals from the plugs and by removing the cable blocks from the magnetos. Next, the clips which hold the cable tubes and the cables to the induction housing should be disconnected. The cables should be slipped through the rubber rings holding them to the push-rod tubes and the whole unit with the tubes and blocks should then be taken from the engine. Remove all spark plugs and the two lockwired cap screws at each magneto drive. If these cap screws cannot be reached, turn the crankshaft with wrench No. FA-70, which should be screwed on the shaft and locked with the propeller nut. The screws holding the magnetos to their brackets should then be taken out and the magnetos removed from the engine. Next the two magneto-drive housings should be taken from the gear case, but these units should not be taken apart. The oil strainer and the relief valve, which will both be found below the oil pump, are then taken off. Remove all nuts holding the gear case to the induction housing and lift off the gear case. Next, remove the timing gear, which is held in place by three cap screws, and pull out the auxiliaries drive shaft just above it. The engine stand is then tilted so that the cylinders are in a horizontal position with the propeller end upwards.

Removing Cylinders. Remove the intake pipes, cylinders, and pistons and disassemble the valves as per instructions under "Top Overhaul."

Removing Crank Case Front Half. Remove the lock ring from the thrust-bearing nut and hold the crankshaft with a wrench to prevent its turning. Unscrew the thrust-bearing nut with a spanner wrench. If this nut is found to be tight, pour some gasoline over it and loosen by driving with a fiber drift. The thrust-bearing cover and the oil slinger immediately below are next removed.

After all gaskets have been taken from the cylinder pads, the seven crank-case nuts are removed and the six bolts through the crank case are driven back. Between cylinders Nos. 4 and 5, instead of a bolt there is a stud, which should not under any circumstances be driven back. The front crank case is now ready to be lifted off and the crankshaft and connecting rods can be lifted out as a unit. The short oil line, the oil sump cover, and the carburetor are detached next, and the engine stand is titled back to the vertical position of the frame. Unscrew all nuts on the rear face of the induction housing and remove the rear half of the crank case.

Detach all cam-follower crabs and take out all cam followers, together with their guides. In order to avoid interchanging, keep each cam follower in its guide. The lock ring holding the cam gear in place is then sprung out of its groove and the cam ring is pulled off, after the end of the sleeve on which the cam ring rides has been inspected for burrs.

Disassembling Crankshaft. The thrust bearing spacer and front ball bearing should be pulled off only in case the ball bearing shows excessive wear and needs replacement or if the bearing or the sleeve is loose on the shaft. Whenever a ball bearing is replaced in the engine, use only "Aircraft Bearings," which are designated by red, white, and blue stripes on the package. The shaft is next clamped in a vise with copper covered jaws gripping one counterweight, shown in Fig. 44, and the master rod is disassembled by removing the four bolts holding the cap to the rod. The link rods should be disassembled from the master rod only in case some parts need to be replaced on account of excessive wear. If a link rod has to be removed, the wrist pin locking bolt and the pin will have to be driven out.

Proceeding, turn the shaft around in the vise and remove the cotter pin, nut ball bearing, and spacer in the rear, and drive out the plug from the crank pin toward the rear after the cotter pin securing it to the cheek has been taken out. Any sediment which has collected in the crank-pin plug must be washed off with gasoline. The coupling and the pin holding it should be left undisturbed in the shaft.

Inspecting and Reconditioning. After the engine is disassembled, all parts should be cleaned in kerosene, then rinsed in gasoline and dried. Inspect all parts on a clean bench, according to the following instructions.

Examine all castings for cracks, preferably with the aid of a large magnifying glass. On all machined surfaces, remove all burrs, as these may cause damage in operation or prevent a joint from being tight. Check all clearances. If the permissible clearance is exceeded, the worn parts must be replaced; and wherever the old part shows any markings for assembly purposes, these must be transferred to the new parts. The new parts put into the engine must be carefully fitted to the clearances specified for each instance. In replacing worn bronze bushings, the new parts must be checked as to their press fit before they are pressed into place. After they are assembled, they must be reamed in a special fixture. After bushings have been reamed to the proper diameter, they must, in most cases, be faced to obtain the proper end clearance.

Crank Case. The crank case should be inspected for burrs on the parting surfaces between the two halves, and the main bearing sleeves should be inspected for tightness in the case and for the fit of the outer races of the ball bearings.

Gear Case. The gear case should be inspected as a unit with the magneto brackets and the oil pump. It is not advisable to remove the oil pump from the gear case unless it is found necessary to replace parts. While the gear case is being washed in clean gasoline, the drive shaft should be turned several times in order to clean the inside of the pump.

Crankshaft. Inspect the crankshaft for straightness, and its journals and the crank pin for roundness. Blow out all oil passages in order to remove any fine particles of dirt. If the journals are scored, they should be polished.

Connecting Rods. If the babbitt in the master rod shows any high spots, scrape same lightly with a sharp scraper. Inspect the bushings in all rods and replace the worn ones.

Tachometer Shaft. Be sure that the tachometer shaft turns freely in its bushing and that the pin holding the gear to the shaft is tight.

Cam Followers and Push Rods. Each cam follower must slide freely in its guide, according to the specified clearance. If the roller shows excessive play on its pin, the entire assembly should be replaced by a new one. The ball ends must be tight on the push rods and be smooth and not show any wear.

Piston and Valves. If necessary, the valves should be ground and the piston and cylinders cleaned for carbon and reconditioned according to the instructions given in "Top Overhauling." If the valve clearance in the guide is found to be excessive, due to wear, the valve guide must be replaced, and in doing so the following instructions must be observed. Heat the cylinder head around the valve guide, by means of a blow torch, to about 300 degrees Fahrenheit. Drive out the old guides from the inside of the cylinder, using the proper tool. Clean off the seat and the bore for the guide in the cylinder head and inspect the new guide for burrs, the presence of which may result in damaging the head. The new guide should be cold when driven in and the temperature of the head should be around 280 degrees Fahrenheit. The guides must be driven home to the shoulder. If the new guide is driven in immediately after the old one has been removed, it will not be necessary to reheat the heads.

After the head has cooled off, the bronze valve seats must be re-cut. For this purpose in the tool equipment there will be found the tool assembly No. FA-69, which includes a 45-degree and a 15-degree cutter, an exhaust and an intake arbor, an exhaust and an intake collar, an adjusting chuck, and a T-handle. The collar is slipped over the guide, the 45-degree cutter is attached to the arbor, which is inserted into the valve guide. If the arbor is tight in the intake valve guide, the latter must be reamed to size with a reamer .344 inches in diameter. The adjusting chuck is attached to the upper end of the arbor and by means of it the cutter is pressed against the valve seat. For cutting the seat, the tool is turned with the T-handle, the chuck being tightened when necessary.

If, after cutting, the seat surface is wider than $\frac{7}{64}$ inch, it is reduced to that width with the 15-degree cutter, proceeding in the same manner as with the 45-degree cutter. After the valve seats have been re-cut, the valves must be ground according to instructions under "Top Overhaul." If the seat surface on the valve is badly pitted or grooved, the valve should be replaced by a new one.

Assembling. After all parts are inspected and properly reconditioned, assemble the engine according to the following instructions. Be sure all parts are cleaned and generously oiled on all moving surfaces as they are being put together, also that dirt does not get into the engine during the building-up process.

A lock washer must be used under all plain nuts. With all castellated nuts, use a cotter pin but no lock washer. In either case if the nut goes against an aluminum part, a plain washer must be used in addition, next to the aluminum. If the nut contacts with a steel or bronze part, no plain washer is used. Be sure to attach the cotter pin or the lockwire as soon as the parts are put together. It is advisable to use new cotter pins and new lockwire when reassembling an engine. For lockwire, metallic belt lacing approximately .047 inches in diameter is recommended.

Crankshaft and Connecting Rods. The crankshaft and connecting rods are assembled on the bench as a unit. First drive the crank-pin plug from the rear into the crank pin and lock it to the check with a cotter pin of the proper size. Then assemble the rear bearing spacer, the rear ball bearing, and the nut to the shaft, in the order given, and secure with a cotter pin.

In case it is found necessary to remove them, attach Nos. 1 and 7 link rods to the master rod, and the other link rods to the cap, all according to the markings on the rods and cap. The wrist pins are marked 1 to 7 on the inside of one end, which end of the pin should be assembled to the marked side of the rod. All of the wrist-pin bolts should be assembled with the threaded end pointing toward the master rod. Next the master rod and the cap are bolted together over the crank pin, while the crankshaft is clamped in a vise. The marked side of the cap and all rods must be assembled toward the propeller end. The four bolts or nuts should be gone over repeatedly and tightened equally before locking them. To the front end of the shaft, assemble the short spacer and the front main bearing if it has been found necessary to remove them for replacement. During this and the following operations, the rear end of the shaft may be rested on a bench or a wooden block with a $\frac{3}{4}$-inch diameter hole to clear the coupling which remains assembled to the shaft. Oil the front ball bearing generously and slip the front half of the crank case over the shaft. Then assemble the long spacer, if it has been removed, and the thrust bearing to the shaft. The trade and size markings of the thrust ball bearing should be placed toward the rear. Next the oil slinger is slipped on with the flat side against the bearing and the thrust-bearing nut is screwed on lightly. The cover gasket is now laid on the front face of the crank case with the cutaway portion over the oil return hole, the thrust bearing is oiled generously, and the thrust-bearing cover is assembled to the case with the marking "Top" toward cylinder No. 1.

Crank Case—Rear Half. Lay the rear half of the crank case on a clean bench with the rear end upward. Assemble the cam follower guides and the cam followers into the case according to their markings. The exhaust guide of cylinder No. 1 is marked A, and the others follow to the right around the crank case in alphabetical order. Attach the crabs which hold the guides in place.

It will be found that the markings on the corresponding push rods and guides are the same. Push all cam followers into their guides as far as possible, then slip the cam disc over the sleeve with the cam side toward the crank case and lock it with the retaining ring. The flat side of the ring must be toward the cam ring. Be sure that the six crank-case bolts are in place with one lifting eye under the head of each of the two upper bolts and a plain washer under the head of the four remaining bolts.

Main Assembly. Attach the induction housing to the assembly stand with from four to six bolts through the mounting lugs. It is advisable to close the seven openings for the intake pipes with wooden plugs or rags in order to prevent dirt and small parts from getting into the engine during the assembling.

The frame of the stand should not be placed in a vertical position. Be sure that the tachometer gear is in place and secured to its shaft by a taper pin, with the split end properly spread. Assemble the idler shaft from the front end, press the Woodruff key into the slot, and drive on the timing-gear hub. Attach the oil-pump coupling to the rear of the shaft by means of the through bolt. The rear half of the crank case with gasket is next attached to the induction housing.

The frame of the assembly stand is now turned to the horizontal position and the carburetor with gasket is attached to the oil sump. The gasoline inlet of the carburetor should point toward the rear. The oil-sump cover and the oil screen with a gasket on either side of it are next attached to the sump.

Oil the rear bearing of the crankshaft, to which the connecting rods and the front crank case are already assembled, and lift the whole unit into the rear case. Cylinder pad marked 1 must be diametrically opposite the carburetor. In order to line up the cylinder pads, attach temporarily any two cylinders opposite each other with a few nuts to each half of the case. Drive the six crank-case bolts through the front half of the case and clamp the two halves firmly together with the seven nuts. Remove the two temporarily attached cylinders and screw the special crank-case wrench FA-70 on the end of the shaft and lock it with the propeller nut.

Tighten the thrust-bearing nut with wrench FA-71 and a hammer, while holding the shaft from turning with the special wrench attached to it. Now turn the crankshaft a few times to be certain that the thrust-bearing nut clears the cover, then lock the thrust bearing to the crankshaft by means of the retaining ring.

Assemble the short oil line with the gaskets, attaching the crankcase end first, then put the cylinder gaskets on the crank-case pads. Assemble the pistons, push rods, cylinders, and intake pipes, according to the instructions given under "Top Overhaul." Turn the frame of the assembly stand to a vertical position and push the auxiliaries drive shaft into its bushing in the induction housing.

Valve Timing. Whenever the cam drive has been taken apart, the valves must be retimed as follows. Turn the idler shaft to get the valves in cylinder No. 1 in the position corresponding to firing top center, in which position both valves of this cylinder are fully closed, while No. 7 intake and No. 2 exhaust valves are both halfway open. Set both rocker arms of cylinder No. 1 to a tappet clearance of .027 inch. Attach the timing disc assembly No. FA-16 and wrench No. FA-70 with the propeller nut to the crankshaft. The key on the crankshaft taper is machined exactly opposite the crank throw, so that when the graduated disc is once set exactly on the timing-disc hub, this setting is good for all engines. Attach the reading pointer which goes with the timing-disc assembly to the two front studs of cylinder flange No. 1.

Set the disc to 10 degrees before top center and slowly turn the idler shaft, by means of the oil-pump coupling, anti-clockwise until the intake valve starts to open. This is easily checked by inserting a .0015-inch feeler between the valve stem and the rocker-arm roller. As soon as the feeler begins to stick, place the idler-shaft gear on the hub and attach it with three cap screws where the holes in the gear match those in the hub. Neither the idler shaft nor the auxiliaries drive shaft should be turned when this is done.

Next check the timing of all four cam lobes to the following values, using a .027-inch feeler.

Intake opens —10° B.T.C.
Intake closes —60° A.B.C.
Exhaust opens—60° B.B.C.
Exhaust closes—10° A.T.C.

Each two full turns of the crankshaft bring the next cam lobe in contact with the valve gear. If in checking it is found that the timing does not correspond to the above figures, check the tappet clearance, which must be exactly .027 inch. If the trouble is not in the tappet clearance, remove the three cap screws holding the timing gear to the hub and attach the gear to the hub in such a way that the intake valve closes as nearly as possible to 60° A.B.C. It will then be found that all the other timing values will be within three degrees of the values given, this slight variation being due to the limits in machining. Do not forget to lockwire the cap screws after the timing is finished and to set all tappet clearances to .010 inch while the engine is cold. This will result in a tappet clearance of approximately .027 inch when the engine is warm.

Gear Case. If for any reason the oil pump has been removed, assemble it to the gear case with a new cork and a Vellumoid gasket, the studded flange toward the right-hand side. Inspect to see whether the pump gears are turning freely. Assemble the gear case and gasket to the induction housing by fitting the oil-pump shaft over the coupling in the idler shaft. After the gear case has been attached, turn the crankshaft and see that the pump gears are moving. Assemble the oil strainer, the gaskets, and the relief valve to the gear case, seeing that the seat on the valve and in the case is clean and smooth. Attach the magneto drives and gaskets to the gear case. All gears should have .004 to .008 inch backlash when cold. Make sure that the magneto drives turn freely.

Magnetos. After having set each magneto to fire as nearly as possible to 32° B.T.C. when fully advanced, by means of the adjustment provided for this purpose on the magneto coupling, slight variations between the breaking of the two magnetos must be eliminated by means of the magneto control rod. Both magnetos should break at the same moment, and this can be determined by using a feeler gauge .0015 inch thick on each magneto. Do not forget to lock the control rod and the breaker covers of the magnetos after adjustment has been made.

Grease the rocker arms and put on all rocker-arm covers. Next all spark-plug gaps are checked to .021 inch and the plugs are screwed into the cylinder heads. It is important that the plugs be screwed in freely by hand before being tightened with the spark-plug wrench.

Attach the two cable tubes to the engine. If wires have been removed from the tube for replacement purposes, push the cables for cylinders Nos. 4 and 5 through the bottom end of the nearest tube and the cables for cylinders Nos. 3 and 6 through the small holes on the side of the nearest tube. All cables going from the left magneto to the right side of the engine and vice versa should be pulled through the clamp near the top attaching lug. Two rubber rings should be used on the cables between each magneto and the cable tubes. From the right-hand magneto the cables are connected to all rear spark plugs, and from the left-hand magneto to the front plugs. Each magneto must be wired according to the firing order, which is 1-3-5-7-2-4-6. A clip is fastened to each cylinder head for the cable leading to the front spark plug. All cables should be held to the push-rod tubes by means of rubber rings. The wiring must be checked for correct connections by following up each cable or by a ringing-in outfit, if one is available. Remove the timing disc and the pointer.

The engine is now ready for mounting in the plane. The long oil line and the exhaust pipes must be assembled after mounting. If an engine is stored after an overhaul or if an engine in service is laid up for any length of time, oil generously all metal parts which do not have a protective coating in order to prevent corrosion.

Installation Check-up. Before the engine is remounted into the airplane, great care must be taken to inspect the bosses on the mounting ring for flatness. Where a detachable engine mount is used, this can easily be done by laying it on a surface plate. Variation in flatness over $\frac{1}{64}$ inch may be taken up by wood veneer washers approximately $\frac{1}{8}$ inch thick. All of the ten $\frac{5}{16}$-inch mounting bolts must be used for attaching the engine to the ship and should be fitted with castellated nuts and cotter pins.

Fuel Supply. The engine is equipped with a Stromberg 2-inch carburetor. The fuel line should be made from $\frac{5}{16}$-inch or $\frac{3}{8}$-inch O. D. tubing. It is advisable to install a fuel strainer between the gas tank and the carburetor. A $\frac{1}{4}$-inch Briggs standard pipe tap is provided for the fuel connection on the carburetor. The minimum fuel head from the bottom of the gas tank to the carburetor should be 20 inches when the plane is standing on the ground. Great care must be taken in installing the fuel line so as to avoid failure in operation. This can be done only by placing flexible joints at convenient places. Only gasoline hose corresponding to the Air Corps specifications and marked by a red line along the side should be used. All fuel lines should be made from seamless copper tubing, heated and quenched after bending. A $\frac{1}{8}$-inch Briggs standard pipe tap is provided on the upper side of the top mounting lug for the installation of a primer.

Oiling System. The oil tank should have a total capacity of approximately five gallons and should be located near the engine, so that its lowest point is slightly above the oil pump when the ship is standing on the ground. The oil pump is located at the rear of the engine approximately $3\frac{1}{8}$ inches below the crankshaft center. The oil lines between the engine and the tank should be made from $\frac{5}{8}$-inch O.D. seamless copper tubing, annealed and quenched after bending so as to remove all bending stresses. If no thermometer is placed in the oil tank, one should be installed in the oil-sump housing cover next to the carburetor, in place of the oil drain plug. The thermometer should have a bulb not over $2\frac{1}{8}$ inches long and should have a range from 100° to 220° F. or 0 to 100° C.

When the tank is full, an air space of approximately 20 per cent of the volume of the tank should be left above the oil level. In other words, a five-gallon tank should never contain more than four gallons of oil. A vent must be placed either in the filler cap or, where the ship is stunted frequently, a $\frac{3}{8}$-inch O.D. vent tube should lead from the top of the tank to the $\frac{1}{4}$-inch pipe tapped hole provided for this purpose in the rear wall of the induction housing.

The oil pressure gauge must be connected with the $\frac{1}{8}$-inch Briggs standard pipe tap on the top side of the gear case by means of $\frac{1}{4}$-inch O.D. copper tubing. Use an elbow fitting at the gear case to clear the tachometer shaft. The oil-pressure gauge should have a range from 0 to 150 pounds per square inch.

For the purpose of cleaning the oil strainer, the engine mounting structure and the cowling must provide for access to the strainer cover at the left side of the engine and to the coil pressure regulating valve at the right side of the engine on the center line of the oil strainer chamber.

Ignition System. Ignition is provided by two Scintilla aircraft magnetos. Where a booster magneto or booster coil is used for starting, a 7MM high-tension wire should be used to make connection from it to the trailing terminal marked H on either one of the two magnetos.

Caution. Never turn the propeller when there is gasoline in the carburetor before it is certain that all magnetos are grounded. The ignition switch must be "off" and all ground wires must be tightly connected to the terminals. This is the only sure safeguard against accidental starting of the engine.

Exhaust Pipes. The exhaust flanges furnished with the engine are to be welded to $1\frac{5}{8}$-inch O.D. of No. 20 gauge steel tubing. If an exhaust ring is desired for collecting the gases from more than two adjacent cylinders, $2\frac{1}{2}$- or 3-inch diameter tubing should be used.

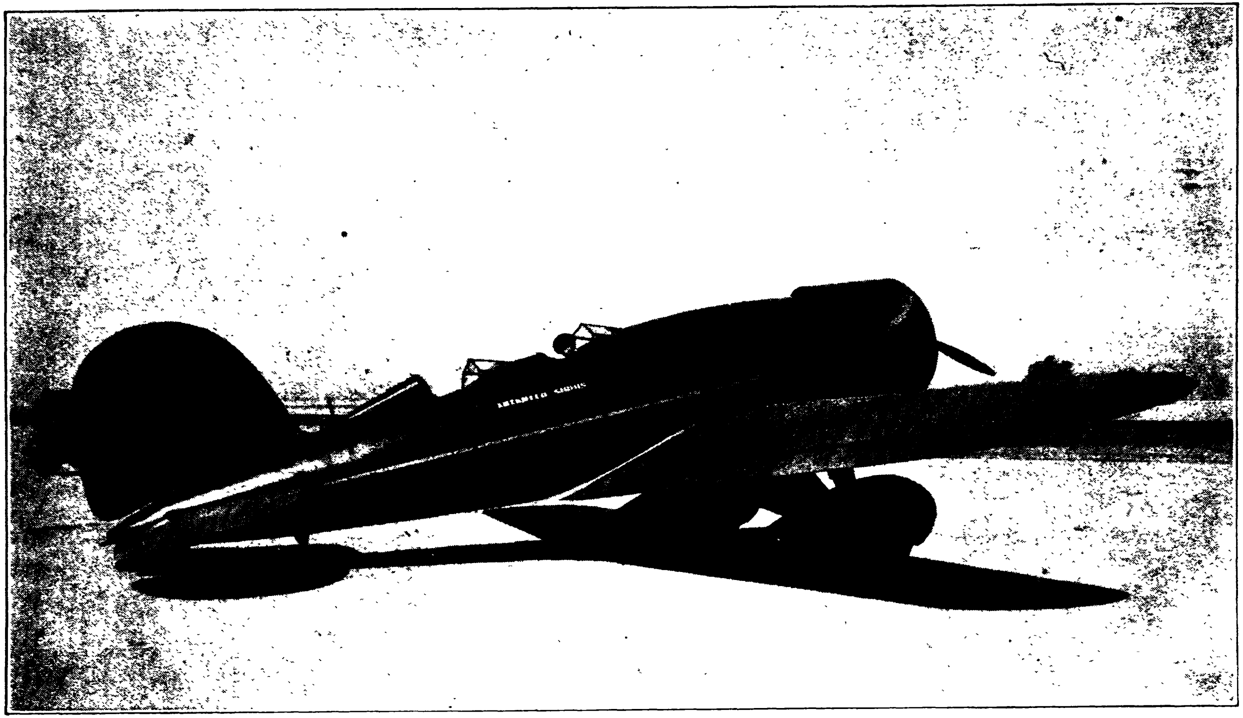
Air Intake. An air heater is furnished with each engine. It is attached to the carburetor and connected with the exhaust flanges of cylinders Nos. 4 and 5. To obtain the best performance of the engine during hot weather, it is advisable to remove the heater with the pipes attached to it. This is done by removing the four cap screws which hold this unit to the carburetor.

Propeller Mounting. The propeller should be designed to allow the engine to turn 1930 to 1960 revolutions per minute at full throttle in level flight. The crankshaft is machined to S.A.E. Standard No. 1 dimensions and is furnished with a key, nut, and cotter pin. The fit of the propeller hub on the shaft should be carefully checked by bluing the crankshaft taper. If the hub does not fit properly, remove the key from the shaft and lap the propeller hub to a perfect fit, with a fine grinding compound. Wash the shaft and hub thoroughly with gasoline and oil parts before assembling them.

Caution. Do not forget to replace the key on the shaft before assembling.

The balance of the propeller should be checked, in both the horizontal and vertical positions, by passing an arbor through the hub and suspending the unit on two parallel knife edges. After the propeller has been attached to the motor in the ship, the track of the blades should be checked. Any point along the edge of one blade must run true with the corresponding point of the other blade within $\frac{1}{16}$ inch. If the variation is greater than this, the reason for it should be determined and remedied. A metal propeller must be adjusted so that the pitch angle for both blades is the same, within one-quarter of a degree. Set the blades to the graduation on the hub if possible, check the setting with a protractor by placing the propeller on a surface plate.

All surfaces and edges of the blades must be smooth. Any signs of pitting at the leading edge of the metal blades should be taken care of immediately by smoothing down with a fine file and emery cloth and finishing with a crocus cloth. It is advisable to re-check the balance of the propeller in case large quantities of metal have been removed by this operation. The blades should be inspected for cracks, at regular intervals. Bent blades may in many instances be straightened, but in order to do this they should be returned to the propeller manufacturer, as elaborate equipment is required for this purpose.



NEW LOCKHEED VEGA AIRPLANE FOR COLONEL LINDBERGH

This airplane is powered with a Wasp engine.

AVIATION ENGINES

PART III

SCINTILLA AIRCRAFT MAGNETOS

The theory of electrical operation is presented here in order that one may have a better conception of the mechanical and the electrical principles involved in the operation of these Scintilla magnetos, which are standard equipment on a number of aircraft engines. Repairs are always better done when the repairman knows the "why" or the theory back of the repair job.

THEORY OF ELECTRICAL OPERATION

Magnetic Field and Contact Breaker. The rotating magnet 1, Fig. 46, has four poles. The poles are joined together inside the laminated ends into pairs—the north poles making up one pair and the south poles making up the other pair. The rotating magnet 1 revolves between the laminated pole shoes 2, producing an alternating field in the core of the coil 3. When the current reaches its maximum value, the breaker cam 5 causes the breaker lever 6 to turn on its axle 7; thus opening the platinum contact points 8 and 10. The short contact screw 10 is connected to the ground 24 through the breaker lever 6 and the main spring for the breaker lever 9, while the long contact screw 8 screws into the insulated support and maintains permanent contact with the primary winding 4 by means of a laminated copper brush fastened on the primary bridge 23. Therefore, when the contact points 8 and 10 are opened, the circuit current is suddenly interrupted, with the result that the magnetic field is broken down and a high-tension spark is induced.

Condenser. The condenser 11 is connected in parallel with the contact points 8 and 10. It prevents abnormal arcing at the points when the primary current is interrupted, thus reducing their wear to a minimum and insuring regular sparking.

High-Tension Current. The interruption of the primary current induces a high-tension current in the secondary winding 12, composed of a large number of turns of fine wire. One end of the secondary winding 12 is connected to the ground 24 through the

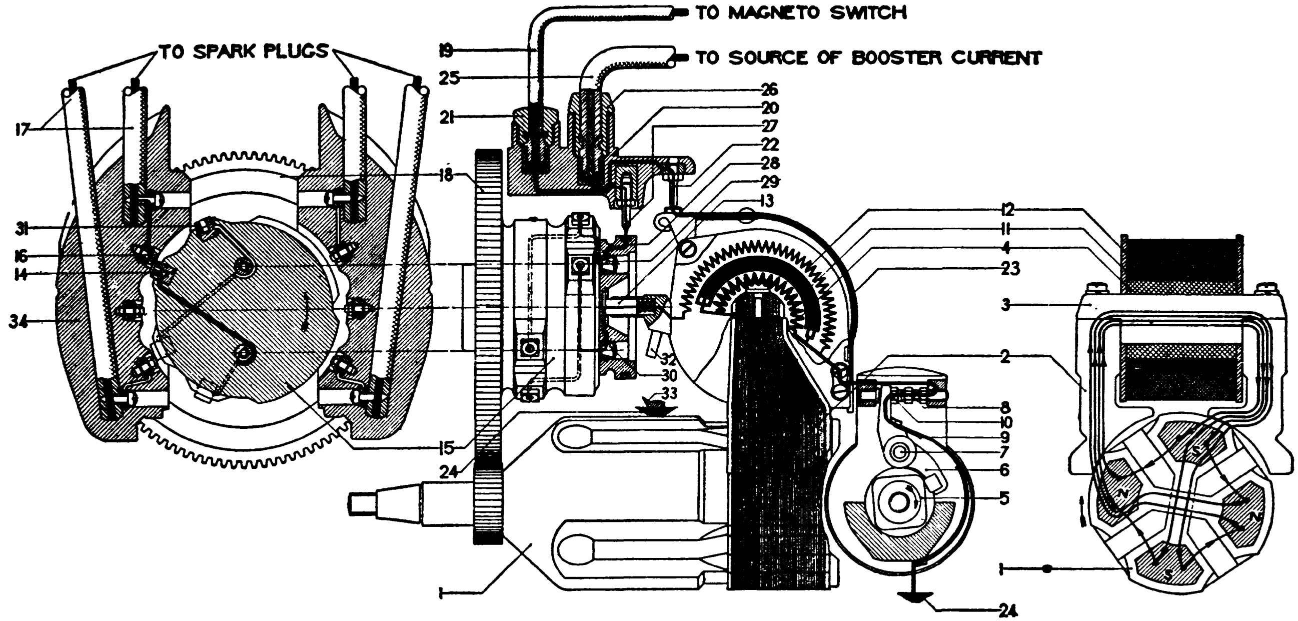


Fig. 46. Diagram of Electric and Magnetic Circuits

1—Rotating Magnet. 2—Pole Shoes. 3—Core of Coil. 4—Primary Winding. 5—Breaker Cam. 6—Breaker Lever. 7—Breaker Lever Axle. 8—Long Contact Point (Insulated). 9—Main Spring for Breaker Lever. 10—Short Contact Point. 11—Condenser. 12—Secondary Winding. 13—High-Tension Carbon Brush. 14—Segment in Distributor Cylinder Carrying Secondary Current. 15—Distributor Cylinder. 16—Electrode in Distributor Block. 17—Ignition Cable. 18—Large Distributor Gear. 19—Ground Wire. 20—Booster and Ground Connection Block. 21—Fastening. Screw for Ground Wire. 22—Stud for Ground Contact. 23—Primary Bridge. 24—Ground through the Magneto and Engine. 25—Booster Cable 26—Fastening Screw for Booster Wire. 27—Electrode for Booster Current. 28—Collector Ring for Booster Current. 29—Fastening Screw for Collector Ring (in Booster Circuit). 30—Fastening Screw for Collector Ring (in Secondary Circuit). 31—Segment in Distributor Cylinder Carrying Booster Current. 32—Safety Gap Electrode. 33—Ground Plate for Safety Gap. 34—Distributor Block.

primary winding 4 and the core of the coil 3, while the other end terminates at the high-tension carbon-brush holder, which is built in as an integral part of the coil.

Distributor. The high-tension carbon brush 13 transmits the current to the spark plugs through the medium of the distributor cylinder 15 and distributor blocks 34 and the ignition cables 17. The high-tension brush 13 bears on the central contact of the collector ring for the booster current 28, which is secured to the distributor cylinder 15 by two fastening screws 29 and 30. The screw 30 is located in the secondary current and connects the central contact in the collector for the booster current 28 with the conductor moulded into the distributor cylinder 15 and leading to segment 14.

The distributor cylinder 15 is fixed on the large distributor gear 18 in a definite position relative to the opening of the contact points 8 and 10 and for a given rotation, which in the diagram is anti-clockwise. Thus the segments 14 successively register with the electrodes 16 in the distributor blocks 34, thereby transmitting the secondary current to the ignition cable 17 and thence to the spark plugs.

Safety Gap. The safety gap is the space between the insulated electrode 32 which screws into the high-tension carbon-brush holder and the electrode 33 on the safety ground plate. Its function is to protect the coil against excessively high voltage by providing a means of escape for the charge, which will jump the gap between the electrodes 32 and 33 in the event of the secondary circuit being accidently broken between the plugs and the coil.

Advance and Retard. The advancing and retarding of the ignition is obtained by moving the breaker assembly about the cam 5. Moving the breaker assembly against the direction of rotation of cam 5 gives advance, while moving the breaker assembly with the direction of rotation gives retard. Since the magneto is in time with the engine, the fuel is fired earlier or later in point of piston travel.

Booster Connection for Starting. The booster cable 25 is held by fastening screw 26. The booster current is carried to the electrode for booster current 27 through the medium of a conductor moulded into the dielectric material of the booster and ground connection block 20 and thence through a small air gap to the collector ring for a booster current 28. The fastening screw for collector ring

29, located in the booster-current circuit, transmits the booster current to the segment 31 in the distributor cylinder 15. The booster current then jumps the air gap to the nearest electrode in the distributor block 34 and thence through the ignition cable 17 to the spark plug. The booster current segment is located in such a manner that it trails the secondary current segment 14.

Stopping the Engine. To stop the engine, the ignition is cut out by neutralizing the functioning of the contact points 8 and 10. This is accomplished as follows: The end of the primary winding 4 terminates through the spring contact on top of the primary bridge 23 and thence through the stud for ground contact 22 to the primary terminal marked P and carrying the fastening screws for ground wire 21. The ground wire 19 goes to a switch located conveniently for the pilot. When the switch is closed, the effect of the contact points 8 and 10 is neutralized by permitting the primary current to flow around the points and through the switch to the ground, thus grounding the primary current and causing the ignition to the engine to cease.

FEATURES OF DESIGN

Instead of the conventional horseshoe magnets, one bell-shaped magnet is used, the rotation of which produces a reversal of magnetic flux through the core of the coil. Note the assembled view Fig. 47. A brass end plate is fastened to the laminated pole extremities of the rotating magnet. This plate carries the inner race for the rear-end ball bearing and the breaker cam. The condenser is incorporated within the stationary coil and is located between the primary and secondary winding. The contact-breaker mechanism is held in position by a bayonet lock and can be completely removed by hand, without the use of any tools.

The Scintilla aircraft magneto, when disassembled for inspection or repair, will consist of the following sub-assemblies: rotating magnet, contact breaker, front and plate coil, magneto housing, main cover with booster and ground-connection block, distributor blocks, and the breaker cover. Important features of design of each of these units are here given.

Rotating Magnet. This unit, Fig. 48, is supported in the magneto housing by the drive end bearing and the breaker end bearing. End play is adjusted by spacing washers behind each inner

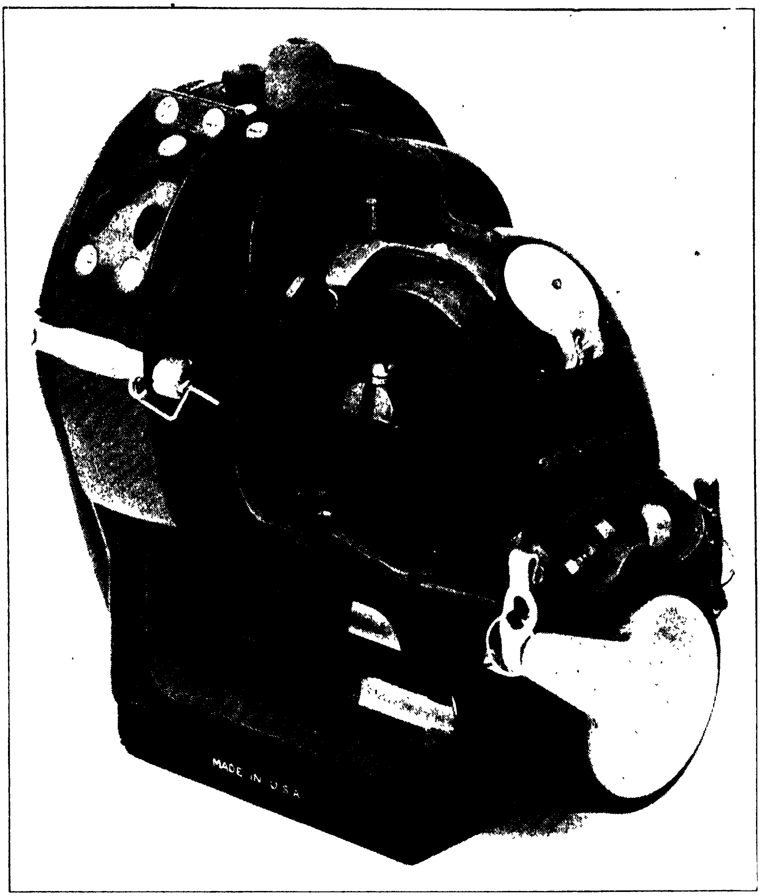


Fig. 47. View of a Sectioned Scintilla Aircraft Engine Magneto

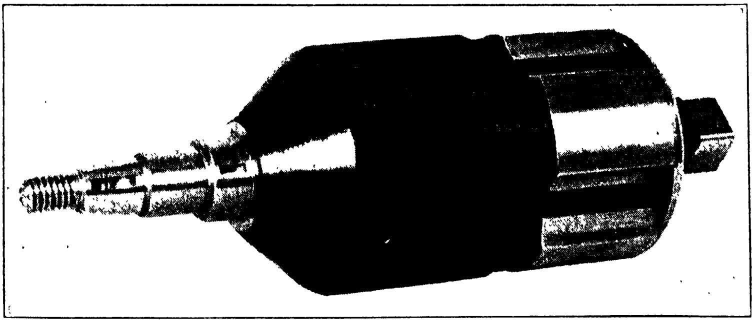


Fig. 48. Rotating Magnet of the Scintilla Magneto

ball race. The drive end shaft carries the inner race for the drive end bearing and the small distributor gear which is keyed to the drive end shaft. The breaker end shaft carries the inner race for the breaker end bearing and the breaker cam. The breaker cam is keyed on a taper shaft and secured by a screw.

Contact-Breaker Assembly. The contact-breaker assembly is shown in Fig. 49. The mechanism is carried by the breaker cage. The breaker cage has the ground and compressing springs riveted to it. It carries the breaker lever and breaker-lever axle, also the short contact screw. The insulated support carrying the long contact screw and fiber stop is mounted at the top of the breaker cage. The flat spiral bayonet lock spring lies between the back of the breaker cage and the dog plate and inside the bayonet lock latch. The oil wick for the cam is located in the bottom of the breaker cage. The main spring for the contact-breaker lever has a short reinforcing spring under the breaker-lever end and a long reinforcing spring under the breaker-cage end. It is fastened by a screw at each end.

Fig. 49. The Scintilla Breaker Assembly and Contact Points

The end cover with the advance lever is held solidly against the back of the contact-breaker assembly by a screw which seats in the breaker cage and screws into the centrally located boss in the end cover. There are two dogs, 180 degrees apart, which fix the position of the advance lever by engaging in holes in the dog plate. The advance lever may be fixed and held in any one of eight positions.

Front End Plate. The front end plate is fastened to the main housing by two studs in the bottom holes and two screws in the upper holes. Its position is fixed by two dowel pins in the front end of the magneto housing. The front end plate holds the outer ball race for the drive end bearing. It also carries the large distributor gear and distributor cylinder upon the distributor-gear axle. The distributor-gear axle is fastened to the end plate by two screws. The distributor gear is locked on its axle by a steel ring which seats in an angular groove in the end of the axle. The steel spacing washer between the back end of the distributor-gear bearing and the spring ring on the axle provides a means of adjustment for the end play of the bearing. The distributor cylinder is locked to the distributor gear by a spring ring. The correct position of the distributor cylinder for a given rotation is fixed by a dog screw, which screws into the distributor gear. The spacing of the distributor cylinder from the gear by a large paper washer assures a tight fit for the spring ring against the distributor cylinder when the ring is pressed into the groove in the distributor gear. The front end plate also carries the distributor block spring clamps.

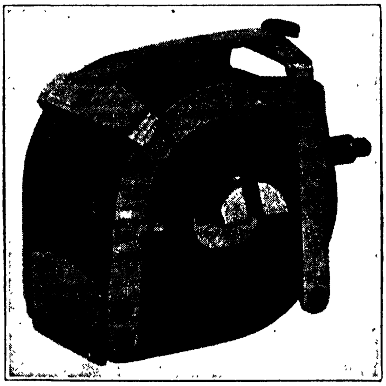


Fig. 50. The Scintilla Coil

Coil. The coil, Fig. 50, is mounted directly on the extensions of the laminated pole shoes, thus insuring the coil a maximum freedom from oil and grease as this mounting puts it well up under the main cover. The pole shoe extensions are ground to insure a good contact with the core of the coil. The coil is held in place by a screw in each end of the core.

The condenser is built in as an integral part of the coil. This assures protection for the condenser and a practically uniform capacity irrespective of temperature and moisture. The high-tension carbon brush holder and safety-gap electrode are mounted on the front of the coil. The ground connection and the spring contact for the insulated support of the stationary contact point are incorporated in the primary bridge, which extends over the top of the coil and is secured by six small screws.

Magneto Housing. This unit encloses the rotating magnet. It carries the outer race for the breaker end bearing, the ground plate for safety gap, the breaker cover spring clamps, and the dowel pins for locating the main cover and breaker cover. The pole shoes are laminated and cast as an integral part of the magneto housing. The breaker stop and fastening screw are located in the lower part of the breaker end of the magneto housing.

Main Cover with Booster and Ground=Connection Block. The main cover is located by four dowel pins and is fastened to the magneto housing by two screws. It affords protection to the coil from moisture, oil, and dirt under abnormally severe operating conditions. The booster and ground-connection block is mounted in the extension of the main cover between the distributor blocks and is secured by two screws. It carries the ground terminal and the stud for ground contact, also the booster terminal and the electrode for the booster current. The stud for ground contact bears on a spring plate secured to the primary bridge. The electrode for the booster current is held directly over the collector ring for the booster current. There is a small air gap between the electrode and the collector ring.

At the top of the main cover is provided numbers for locating the distributor blocks, an arrow showing the direction of rotation of the magneto and the two letters H and P mark the booster and ground terminals, respectively.

Distributor Blocks. These distributor blocks are mounted so that they are held between the main cover and front end plate. Their lower ends rest upon the magneto housing, while the upper ends fit against the top extension of the main cover. They are held in place by spring clamps and are designated as the right and left distributor block as viewed from the drive end.

Breaker Cover. The breaker cover is located on the magneto housing by two dowel pins and held in place by a spring clamp at each end. It is directly over the contact points and, when removed, permits of a ready inspection of the points or removal of the contact-breaker assembly.

DISASSEMBLING SCINTILLA MAGNETOS

The relation of parts and their names are shown in Fig. 51. When disassembling the magneto, use great care and the proper tools. First remove the safety pin on the breaker cover and the distributor block spring clamp. Then release the spring clamps and remove the breaker cover by lifting it straight up. Next remove the breaker assembly. This is readily accomplished by moving the breaker to midway between advance and retard positions. Now bring the bayonet lock hand latch to a vertical position, which unlocks the bayonet lock, and pull the breaker assembly outward.

Release the spring clamps and remove the distributor blocks. Then unscrew the fastening screws for the magneto cover and remove it by lifting straight up until the cover clears the coil. Should the cover be tight on the dowel pins, it can be loosened by alternately tapping it with a fiber drift on the rear edge just over the breaker compartment and lifting the front by hand.

Unscrew the fastening screw in each end of the core of the coil and remove the coil by pulling it back until the high-tension brush clears the distributor cylinder, then lift the coil out. Care should be exercised in removing the coil. Do not pull straight up on it until the high-tension brush clears the face of the distributor cylinder. Some coils fit fairly tight between the pole-shoe extensions and when they release themselves under a vertical pull, they will do so quite suddenly and the high-tension brush will be broken and possibly its holder torn loose from the coil; hence the injunction—move the coil back until the high-tension brush clears the face of the distributor cylinder, then it may be lifted out.

Remove the two fastening screws and the two nuts and lock washers from each of the bottom studs, then pull the front end

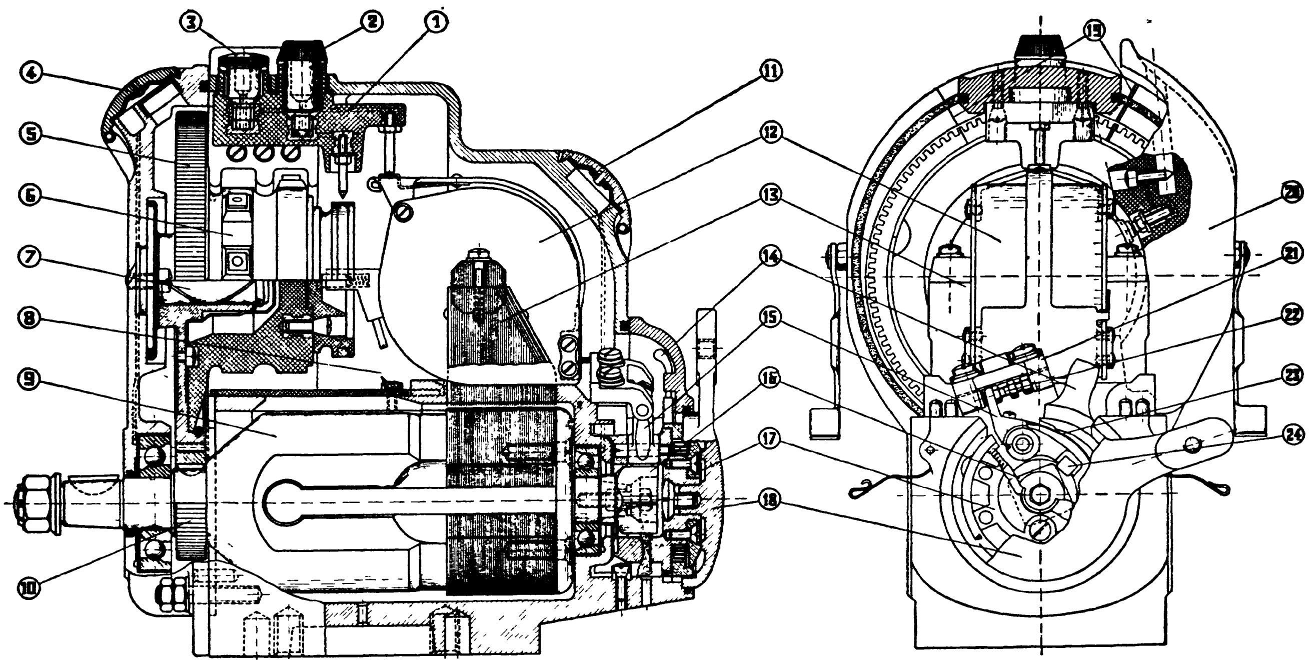


Fig. 51. Sectional Drawing of Scintilla Aircraft Magneto

1—Booster and Ground Connection Block. 2—Fastening Screw for Booster Wire. 3—Fastening Screw for Ground Wire. 4—Front Oil Hole and Timing Window Cover. 5—Distributor Gear. 6—Distributor Cylinder. 7—Distributor Gear Axle. 8—Safety Gap. 9—Rotating Magnet. 10—Small Distributor Gear. 11—Rear Oil Hole Cover. 12—Coil. 13—Laminated Pole Shoes. 14—Bayonet Lock Latch. 15—Contact Breaker Lever. 16—Cam. 17—Dog Plate. 18—End Cover with Advance Lever. 19—Timing Marks. 20—Distributor Block. 21—Insulated Support. 22—Contact Points. 23—Breaker Lever Main Spring. 24—Cam Follower.

plate off. If the end plate should fit tight, it may be loosened by alternately tapping it gently on each side of the inside surface with a rawhide mallet.

Next remove the rotating magnet. This is easily accomplished by turning the rotating magnet until an opening between any two poles of the magnet appears in the center between the top edges of the pole shoes. This allows the flat surfaces of the magnet to be in such a position that the rotating magnet can be readily withdrawn from the magneto housing.

Take the distributor cylinder off the large distributor gear by releasing the spring ring that holds it. There is a recess in the outer edge of the distributor cylinder flange for the ends of the spring ring. The ring may be released by prying with a small screwdriver between the flat part of the ring and the inside of the distributor gear, thus forcing the end in far enough to clear the groove cut for it. When the ring is released, the distributor cylinder may be lifted off. Remove the large distributor gear by first releasing the small steel spring ring, then removing the spacing washers and lifting the gear off the axle shaft. Finally remove the end cover with advance lever from the breaker assembly by unscrewing the fastening screw in back of the breaker cage.

Cleaning. All parts may be washed in gasoline and dried with compressed air except the coil. Wipe all pieces of dielectric material with an oil-saturated cloth after cleaning. There are, however, several precautions to be observed in drying off the parts. The numbered discs in the distributor blocks and those on the top of the main cover must not be exposed to full air pressure. Hold them at a safe distance or else allow them to dry in the open air. Great care should be taken that the felt strips in the magneto housing, the main cover, the breaker cover, and the front end plate are not loosened or torn out by the air pressure. Oil all felt strips after they have been cleaned.

It is imperative that the cage and bearing assembly of each bearing be held so that they cannot spin when using air for cleaning. This will prevent throwing out the balls and making it necessary to obtain a new cage and ball assembly to complete the bearing for reassembly. Keep the rotating magnet clean inside and out. Do not lay it near small screws, nuts, or metal chips, etc. Its construction is such that any foreign material adhering to it will result in serious injury to the magneto. After cleaning the rotating magnet, grease it thoroughly to prevent rust.

INSPECTION OF PARTS

It is anticipated that the inspection and repair of the Scintilla aircraft magneto will offer very little, if any, difficulty to the average ignition mechanic who has had experience with other types of magnetos. Therefore only such instructions as are deemed necessary to cover certain features which are characteristic of the Scintilla aircraft magneto are here given.

Magneto Housing. The breaker stop and the safety-gap ground plate must be tight and their fastening screws locked. Have the $\frac{3}{8}$-inch cap screw hold-down holes clean and threads straight. Lap the base just enough to see that its surface is smooth. It is imperative that the oil lead to the back bearing be open and clean. Flush with a good grade of light oil after cleaning.

Front End Plate. Lift the oil wick and the spring out of the distributor gear axle. Clean the oil leads to the axle and front end bearing and flush with a good grade of light oil. Replace the oil wick in the distributor gear axle. See that the fastening screws for the distributor gear axle are tight and locked to the outside surface of the front end plate.

Examine the large distributor gear to see that there are no burrs on the teeth of the gear. Replace the gear, taking care to hold the wick down until covered by the gear bearing. Replace the spacing washers and the spring ring. Try the end play of the gear on the shaft. If not less than .005 inch or more than .008 inch, it is satisfactory. Test the dog screw. It must be tight and locked to the large distributor gear.

Replace the paper spacing washer and distributor cylinder. Replace the spring ring. The total thickness of the spacing washer should be such that the distributor cylinder will be held tightly against the distributor gear. Force the spring ring into its groove throughout its length.

Breaker Assembly. Replace the end cover with the advance lever on the breaker assembly. Place the assembly in position in the magneto housing and note that it functions properly. The bayonet lock latch, when released, should snap into position and the breaker will spring over to full advance. Remove the breaker and lay aside for adjustment during final assembly.

Main Cover. Clean the oil lead to the back bearing thoroughly. Examine the booster and ground-connection block in the top of the main cover, especially around the terminal marked II, as any small cracks in the material would ground the booster current.

Coil. Note that the secondary brush holder is solid with the coil. It is of vital importance that the spring contacts on the primary bridge be in good condition. The rear spring bears against the face of the insulated support on top of the breaker cage, while the front spring located above the coil makes contact with the ground contact stud.

Distributor Blocks. Examine the electrodes. Be sure that they are screwed tight into the distributor blocks. Loose numbered discs must be glued with a water- and oil-proof glue. After the glue is dry, apply white shellac as an added precaution.

Rotating Magnet Assembly. Check the cam fastening screw. Note the condition of the ball bearings. It will be noticed that the cage and balls of the front bearing are a loose part on the AG 12-D rotating magnet, while on the AG 8-D and AG 9-D rotating magnets they stay on the inner race. This allows the balls to clear the large distributor gear during the assembly of the AG 12-D. All types of rotating magnets carry the cage and balls for the rear bearing on the inner race.

Examine the laminated pole end of the magnet for any signs of rubbing due to foreign material lodging between laminated ends of the magnet and the pole shoes. The clearance between the laminated poles and pole shoes is .002 inch. This explains the necessity of keeping them clean and free from any foreign material which could cause them to strike the pole shoes and wreck the magneto.

REASSEMBLING THE MAGNETO

While the Scintilla parts are readily interchangeable in each type of magneto and for a given rotation will function in another magneto of the same rotation, much time and effort will be saved by using the same rotating magnet, magneto housing, and front end plate in the reassembly.

The end play and bearing fit of the rotor in the magneto in most instances will be found correct. The rotating magnet 9, Fig. 51, was taken as the last sub-assembly for inspection so that when it was cleaned up it could be installed in the magneto housing immediately. Have the magneto housing clean and ready to receive the rotating magnet. Next take up the rotating magnet and fill the rear ball cage with good grease. Grease the magnet all over, leaving a film of grease to prevent rust.

Recharge the rotating magnet, clean off metal particles that may be adhering to the poles, and place in the housing at once. The magnet is easily replaced by turning it until a flat surface is at the top, then pushing it in place. Now turn the rotating magnet right or left 45 degrees or until the same space between the top of the pole shoes is filled by one of the poles of the magnet. This is the neutral position for the rotating magnet and it should always be left in this position unless there is a keeper across the pole-shoe extensions.

Fill the cage and ball assembly for the front bearing with grease, put it on over the shaft, and place it on the inner race. If the magneto is an AG 12-D, the cage and ball assembly must be placed in the outer race in the front end plate and assembled with it. Next observe the arrow on top of the main cover to find the direction of rotation for which internal timing was originally set. If the arrow points anti-clockwise, as viewed from the drive end of the magnet, match all timing marks G. If the arrow points clockwise, match all timing marks D. Suppose the magneto to be assembled is an anti-clockwise or left-hand rotation. Turn the rotating magnet until the marked tooth on the back of the small distrbutor gear is up in view so that it may be matched with the marked tooth on the large distributor gear. Next take up the front end plate and put it on over the drive end shaft until the edges of the gears are about to touch, holding the plate in one hand and guide the mark on the large distributor gear by turning the distributor cylinder with the other hand. When the marked tooth on the small gear and the marked tooth on the large distributor gear are matched, push the front end plate up against the magneto housing and secure it by means of the two screws and studs provided.

Now test the magnet for end play. There should be none. The bearings should be just tight enough so that when the magnet is turned about 30 degrees from the neutral position, it will be returned to the neutral position by the magnetic pull.

Replace the breaker assembly for the final setting. Set the contact points 22, Fig. 51, so that their maximum opening will be .012 inch. The small gauge on the Scintilla contact-point wrench may be used for this purpose. When contact points are set at .012 inch for maximum opening, the clearance between the back of the breaker arm and the face of the fiber stop should be from .002 to .010 inch. Check clearance on each cam lobe. The cam must run true within .0005 inch.

The internal timing of the magneto must now be checked. Turn the rotating magnet until figure 1 on the large distributor gear is in line with the mark in the timing window. The supplemental timing marks, located on the inside edges of the large distributor gear and the front end plate, should also be in line at this time. By slowly rocking the rotating magnet with the breaker in full advance position, the points should be just on the instant of opening as No. 1 and its mark and the supplemental timing marks 19, Fig. 51, come in line with each other. Hold the rotating magnet with the timing marks in line and with one hand place the right distributor block in position. When the magneto is correctly timed, the No. 1 electrode will coincide with a segment on the distributor cylinder.

Remove the breaker assembly. This permits an easier installation of the coil. Place the coil 12, Fig. 51, between the pole-shoe extremities. This is best accomplished by sliding the coil in from the back and moving it forward into position. The coil fits tight and often causes the pole-shoe extensions to shear off a very thin piece of the fiber side plate. Take every precaution that none of this fiber gets in between the ends of the core of the coil and the ends of the pole-shoe extensions. Secure the coil with a fastening screw in each end of the core. Replace the breaker assembly. Spin the magneto and, if properly assembled and timed, a good snappy blue spark will jump across the safety gap. The safety gap should be not less than $\frac{3}{8}$ or more than $\frac{1}{2}$ inch.

Put the main cover in place. Take great care that it fits the housing. Have the bottom edges of the main cover smooth. It is important that the cover fits the housing accurately, since the top extension of the cover acts as a stop for the distributor blocks while the housing supports them at their lower end. Any serious misalignment would result in injury to the electrodes in the distributor blocks and segments in the distributor cylinder. Fasten the main cover to the housing with the two long screws provided. Replace the breaker cover. Fasten the spring clamps and safety. Replace the distributor blocks. Match them up with the number discs on the sides of the top of the main cover. Fasten the distributor block spring clamps in place and safety. This completes the final assembly.

Mechanical Check-Up. Where the equipment is available, the magneto should be tested immediately after the final assembly is completed. Its operation during the bench test gives the experienced mechanic an accurate knowledge of the mechanical and electrical condition of the magneto. In order to make the test, mount the magneto on the test bench and remove the breaker assembly. Run the magneto up to about 1,000 revolutions per minute and listen carefully to its running. The period of any unusual or irregular noise as compared with the drive-shaft speed will give a good indication as to its origin. While listening to the magneto, note the hum of the gears. When running properly, they will have a consistent hum. The pitch of this hum will vary slightly for different magnetos but will be consistent for a given magneto.

When there is foreign material imbedded in the face of the large gear, it will cause an audible click or knock each time it is turned against the small distributor gear. When foreign matter is imbedded in the face of the small distributor gear, the period of the knock will be that of the drive-shaft rotation since the small gear is keyed to the drive shaft. Should the gears run irregularly and tend to chatter, there is excessive play either in the distributor-gear axle bearing or between the teeth of the gears. If there is a knock in the magneto housing, it is usually caused by the laminated poles hitting the pole shoes.

Most trouble in the magneto housing is caused by small metal parts, such as filings, chips, broken lock washers, etc., that are picked up while the rotating magnet is lying on the bench. They are thrown out by centrifugal force and cause serious damage to the rotating magnet and pole shoes. Unusual tightness or rubbing in the housing may be noticed by the magneto running exceptionally warm during the test. If the condition is bad, it will be noticed by an irregular and unusually hard turning when the drive shaft is turned by hand prior to the test run.

Electrical Check-Up. Replace the breaker assembly and wire up the distributor blocks to spark gap, which should be of the three-electrodes type in order to obtain good and consistent results for testing. The third electrode is a static point located so that it meets the live point at an angle of 90 degrees and is set with an air gap of about .002 inch between static point and live point. The live point is the one connected to the distributor block by the high-tension cable. The gap between the live point and grounded point is to be 7 mm. ($\frac{9}{32}$ inch). Keep all points sharp and clean to obtain best results.

Run the magneto for about ten minutes at a speed of 900 to 1000 revolutions per minute. Observe the contact points at the start of the test. Should they arc excessively, remove the breaker and clean the points thoroughly. Have the points dry and free from grease before replacing breaker. After ten minutes at above speed, run the magneto up to 2800 revolutions per minute and maintain this speed for at least five minutes. Observe the contact points. There should be very little sparking at the points when they are clean and seat properly on their contact area.

Test the primary grounding circuit at this stage of the test with a piece of wire. Put one end of the wire in the hole in the fastening screw for the ground wire and touch the other end to the magneto body or frame of the test stand. The spark across the gap should cease the instant the free end of the grounding wire is touched to the magneto or the frame of the test stand. The next running speed should be not less than 3500 revolutions per minute while 4000 revolutions per minute is desirable. Maintain this speed for at least ten minutes. Observe the spark closely. A consistent miss can readily be detected.

A slight scattering miss will be detected by a momentary break in the spark flame between the electrodes. A magneto, the internal timing and assembly of which is correct, will regularly fire across a 7 mm. air gap at 4000 revolutions per minute. Observe the contact points. They should run practically free from arcing by the time the test has progressed thus far. After the high-speed test, the next test is to obtain the coming-in speeds. The coming-in speed is the lowest speed at which the magneto will come in and fire consistently across the 7 mm. air gap. The maximum coming-in speed allowed for full advance is 120 revolutions per minute while that for full retard is 240 revolutions per minute. Coming-in speeds higher than those just given would indicate a magneto of low electrical efficiency. This may be due to improper internal timing or to the rotor having lost some of its magnetism through improper handling after being recharged or by spinning the rotating magnet without a keeper across the pole-shoe extensions.

The booster starting circuit should be tested after the finish of the running test. Use a hand magneto or vibrating high-tension coil as the source of high-tension current. Connect the high-tension booster current cable to terminal marked H. This is 2 in Fig. 51. Rotate the magneto by hand. Start with No. 1 in the timing window and observe that a spark jumps all gaps in the correct serial order as given by the numbers on the distributor blocks. Bear in mind that because the booster segment trails the service segment of the distributor cylinder, the booster spark will occur late. For example, when No. 1 shows in the timing window, the booster current will jump No. 12 gap. The same principle applies to the eight- and nine-cylinder magnetos. A deviation from this serial order or no spark at all across the gap indicates that the booster circuit is not correct. Examine parts for fine cracks or burnt spots, indicating a short circuit of the booster current.

INSTALLING MAGNETO ON ENGINE

Make sure that the magneto-shaft half of the drive coupling is seated and keyed on the taper of the drive shaft and then locked by the nut and washer and made safe with a cotter pin. Spin the magneto and note that the drive-shaft half of the coupling runs true. Inspect the magneto base. See that the $\frac{3}{8}$-16 thread in the hold-down holes has not been stripped or that the start of the thread has not been closed, thus having a tendency to cause the cap screw to cross threads. When necessary, clear up the threads with a $\frac{3}{8}$-16 tap and then clean the holes thoroughly. Note the dowel pin holes. They should fit the pins very snugly but not so tight as to cause difficulty in getting the magneto down on the surface of its support. See that the base of the magneto is smooth and makes good contact with the bracket surface.

Having made use of the above instructions and any other information that the mechanic has found to be useful, the magneto is ready to be secured. It is imperative that the length of the $\frac{3}{8}$-16 cap screws be correct. When in doubt as to the correct length, it can best be obtained by direct measurement. Making allowance for the thickness of the washer used on the screw, the length must be such that when the screw is tight it will not have less than $\frac{7}{16}$ or more than $\frac{1}{2}$ inch of its threaded length in the $\frac{3}{8}$-16 hole in the base of the magneto. When the correct length is established, draw the screw up tight and safety.

Timing the Magneto to the Engine. Turn the engine slowly as the piston in cylinder No. 1 comes up on compression. Stop when the full advance position for the ignition, as given by the engine manufacturer, is reached. This point is given in degrees before top center (B.T.C.), and is marked on the timing disc to be used with the engine. At this point the magneto is to be coupled to the engine, the following instructions having been carefully noted and followed.

The No. 1 on the large distributor gear can be seen through the timing window located under the front oil-hole cover. When this No. 1 is in line with the white mark at the top of the timing window, it indicates that the contact points are at the same instant of opening with the breaker fully advanced and the No. 1 electrode on the distributor block is registering with the proper segment on the distributor cylinder.

Some installations do not permit of this window being used. In such cases, the supplemental timing marks must be used. They are located on the inside surface of the large distributor gear 19, Fig. 51, and the front end plate and are so arranged that when they coincide with one another the contact points are at the instant of opening.

Fasten the spark-plug cables to the distributor blocks. The numbers on the distributor blocks show the serial firing order of the magneto. The numbers on the top of the main cover are for the purpose of locating the right and left distributor blocks to their respective sides. Observe that each magneto is wired to its proper set of wires as given by the engine manufacturer and that the wires lead from the magneto so that No. 1 on the distributor block goes to the first cylinder in the firing order of the engine; No. 2 on the distributor block goes to the second cylinder in the firing order of the engine;

No. 3 on the distributor block goes to the third cylinder in the firing order of the engine, etc., until all cylinders have been wired in their proper firing order. Clamp the distributor blocks in place.

The letter H marks the terminal to which the booster wire is to be connected. The letter P marks the terminal 3, Fig. 51, to which the ground or short circuiting wire from the magneto switch is to be connected. The arrow indicates the direction of rotation of the magneto when viewed from the drive end. Tighten and lock the drive coupling. The advance lever linkage is to be connected to the advance lever on the magneto, special attention being given that full advance and retard are obtained when the spark lever in the cockpit is moved to its full advance and retard positions.

Contact Points. The life of the contact points depends to a great extent on how clean they are kept. Therefore, take particular pains to keep them as clean as possible. File them only when it becomes absolutely necessary for the best operation of the magneto. The gap between contact points when fully opened should be maintained at .012 inch. Use the gauge on the Scintilla wrench for this purpose. Keep the points in alignment.

Adjusting Fiber Stop. The fiber stop is mounted in the insulated support just back of the top of the breaker lever. Its function is to limit the travel of the breaker lever at high magneto speeds. The fiber-stop clearance is measured between the face of the stop and the back of the breaker lever. The clearance must be measured with the points fully opened. The fiber-stop clearance must not be less than .002 inch. This may be obtained in a practical way by using a .002-inch feeler, placing it behind the breaker lever, and turning the rotating magnet until the points are at their maximum opening. The tension on the feeler as it is pulled from between the back of the breaker lever and the fiber-stop should be just enough to allow it to be withdrawn easily.

Care should be taken in filing the fiber stop so that when the proper clearance is obtained and the breaker lever is pushed back against the stop, the whole surface of the stop bears against the back of the breaker lever. It is impractical to state a maximum fiber-stop clearance which could be applied impartially to all Scintilla aircraft magnetos, inasmuch as the fiber stops and cam followers and contact points do not wear exactly alike.

Distributor-Block Electrode Clearance. There will be very little necessity for putting in new electrodes in the distributor blocks. However, should it become necessary, it is very important that they have the correct clearance. The minimum clearance should be .030 inch. The maximum clearance should not be over .050 inch. Templates for measuring these clearances may be obtained from the manufacturer.

Adjusting Mesh of Large Distributor Gear. This adjustment will rarely be found necessary. In the event that the large distributor gear requires replacement, adjust the gear as follows. To raise the gear, loosen the fastening screws on the distributor-gear axle flange and drift the axle slightly to the right as viewed from the distributor-gear side of the front end plate. To lower the gear, drift the axle slightly to the left. Tighten the fastening screws for the distributor-gear axle and lock the outer ends to the outside surface of the front end plate.

Timing Magneto by Means of Lights. This practice can be followed very easily while the magneto is on the repair bench and the coil is not installed, and it will serve as a very accurate means of checking the internal timing of the magneto. Once the coil is installed, however, and the magneto is mounted on the engine, the timing marks on the magneto will be found sufficiently accurate to meet all practical requirements for timing the magneto to the engine. However, with the coil in place, the internal circuits and construction of the magneto are such that if an external source of current is applied to the contact points, there is the danger of the coil acting as an electromagnet and weakening the magnetic qualities of the rotating magnet, thus impairing the efficiency of the magneto.

Oiling the Magneto. Proper oiling is of vital importance for the satisfactory operation of the magneto. Use the best grade of medium-bodied oil obtainable. Put from 30 to 40 drops of oil in the front oil holes 4, Fig. 51, or until it appears at the overflow hole for the distributor-gear axle bearing. This hole is located about one inch below the front oil-hole cover. Put about three to five drops of oil in the back oil hole. See that the felt wick in the bottom of the breaker cage is thoroughly saturated with a heavy-bodied oil. Oil the magneto thereafter at regular intervals of about 25 hours operation.

STROMBERG AIRPLANE ENGINE CARBURETORS

CARBURETOR DESIGN

Mixture Control. As the airplane ascends in altitude, the atmosphere decreases in pressure, temperature, and density. The weight of the air charge taken into the engine decreases with the decrease in air density, cutting down the power in about the same percentage. In addition, the mixture proportion delivered by the carburetor is affected, the mixture becoming richer at a rate inversely proportional to the square foot of change in air density.

In order to compensate for this change in mixture, a manually-operated mixture control is provided on all Stromberg aircraft carburetors. The mixture supplied by a carburetor may be made leaner by reducing the effective suction on the metering systems, by restricting the flow of fuel through the metering system, or by admitting additional air into the induction system through an auxiliary air entrance. Each one of these methods has been used in Stromberg aircraft carburetors.

Float-Chamber Suction Control. The float-chamber suction type of control, sometimes called back-suction control, operates to reduce the fuel flow by placing a certain proportion of the air-passage suction upon the fuel in the float chamber so that it opposes the suction existing in the main discharge jet. Figs. 52, 53, and 54 show the general arrangement of this type of control. The simple carburetor illustrated has a venturi, a fuel nozzle, and a float-chamber fuel supply with two openings at the top—one connected to the same suction as the fuel nozzle and the other connected to a region of no suction. In Fig. 52 a valve *A* is shown in the suction opening. With this valve closed, there is the ordinary condition of carburetor action with suction on the jet and no suction but simply atmospheric pressure on the float chamber. This condition exists when the mixture control is in the full-rich position. If this valve is opened, some of the suction existing on the jet is imposed on the float chamber, which opposes the jet suction and decreases the fuel flow.

In Fig. 53 a valve *A* is shown in the passage opening to the atmosphere. With the valve closed, no fuel would discharge because the suction would be the same on either side of the jet system. There would, of course, be suction above the fuel in the float chamber, which would tend to draw more fuel through the needle opening *D;* but provided the float were sufficiently large, the valve *C* would hold shut and maintain the level in the float chamber at the normal height. This corresponds to the extreme lean condition that would be obtained with this type of control in which there would be no fuel flowing. As this valve is opened, air is admitted to the float chamber, thus reducing the suction on one side of the jet system, and fuel flow will start due to the higher suction at the jet in the venturi. With the mixture control in full-rich position, this valve is wide open.

In actual construction the suction connection is taken from a location of lower suction and a small restriction of fixed size placed in this passage, as shown by Fig. 54. With this arrangement, the

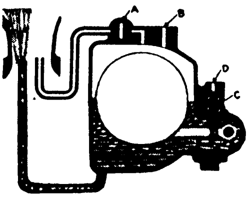


Fig. 52. Mixture Control Valve in Suction Passage—Full Rich Position

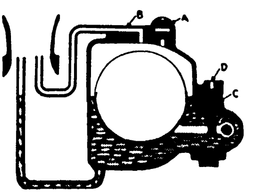


Fig. 53. Mixture Control Valve in Passage to Atmosphere —Full Lean Position

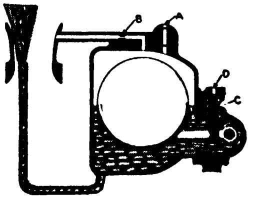


Fig. 54. Arrangement Used in Stromberg Carburetors

valve *A* may be completely closed without entirely stopping the flow of fuel. With the valve in intermediate positions, the pressure in the float chamber will not be equal to the full suction on the jet nor will it be atmospheric pressure, but somewhere between, depending on the valve opening. With the valve *A* in a fixed position, the pressure in the float chamber will always be the same percentage of the suction at the discharge nozzle regardless of how this suction may vary, so the action is uniform at all working speeds.

In order to obtain a control that is not too sensitive to adjust, the closure of the valve must be rapid at first and then more gradual, and this is obtained by the use of a peculiarly-shaped flat-disc valve working upon an elongated slot, as shown in Fig. 55. This type of valve produces changes in the mixture ratio directly proportional to the valve movement.

Air-Port Control. The air-port control operates by by-passing part of the air charge around the venturi tube and fuel jet and reducing both the air velocity and the suction existing at the main discharge jet. The air is taken from the carburetor inlet and enters the carburetor barrel just above the venturi tube, as shown in Fig. 56. On some models a screen with vertical perforations is used to admit the air equally around the carburetor barrel and also to permit fuel to drain down the intake passage without finding its way into the air-port chamber, which might take place with low engine speeds at low altitudes when the air-port valve is closed. The air-port type of control has the advantage that it slightly increases the air-volume capacity of the carburetor with increasing altitude; but the allowable reduction of velocity past the jet reaches a limit at about 20,000 feet, and this type of control is, therefore, not suitable for extremely high-altitude service. The air-port control also requires an increase in carburetor size, which often prevents its use when space is limited as, for instance, in the Vee of a twelve-cylinder engine.

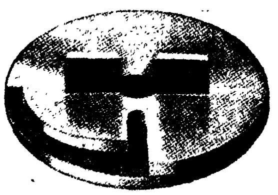


Fig. 55. Altitude Control Disk Valve and Plate on Which It Seats

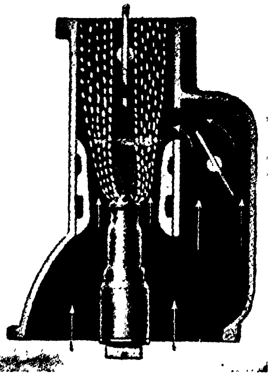


Fig. 56. Air-Port Type of Mixture Control

Needle-Valve Control. The needle-valve type of mixture control is used to restrict the fuel passage to the main discharge jet, as shown in Fig. 57. With the mixture control in the full-rich position, the needle is in the raised position, and the fuel is accurately metered by the main restriction in the fuel passage. To lean out the mixture, the needle is lowered into the needle-valve seat, thus reducing the fuel supply to the main discharge jet. A small by-pass hole from the float chamber to the fuel passage permits some fuel to flow even though the needle valve is completely closed. The size of this by-pass opening determines the range of control.

Automaticity of Control. It will be noted that all of the control methods mentioned preserve the automaticity of the mixture range, that is, any given setting of the control reduces the suction of the fuel flow through the jet by the same percentage at all engine speeds. Since the delivery of the jet bears a constant ratio to the suction, any given setting of the control has a substantially uniform effect upon the mixture at all engine speeds during which the main jet is in operation. None of these types of controls affect the idling-jet operation.

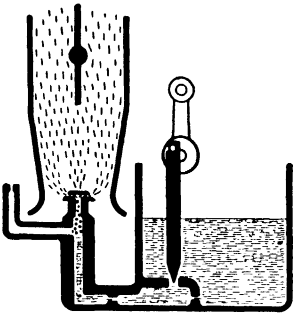


Fig. 57. Needle-Valve Type Mixture Control, with Main Discharge Jet

Altitude Mixture-Control Range. The range of the mixture control is usually designated in terms of altitude. This means that a carburetor having a correction range of 20,000 feet will give the same mixture ratio at this altitude with the mixture control set full lean as it would give at sea-level altitude with the control set full-rich. If a metering-jet setting is used which gives a mixture richer than necessary on the ground with the idea of using the mixture control to correct for this condition, the remaining control available for altitude use will be less than if the ground-level jet setting was correct with the control full rich.

The float-chamber suction type and the needle-valve type of mixture controls have a correction range of approximately 25,000 feet altitude, while the air-port type has a range of 20,000 feet. After the limit of mixture-control correction has been reached, the airplane can ascend 5,000 to 6,000 feet higher before the mixture will become rich enough to cause the engine to lose power and several thousand feet more before the engine operation becomes excessively rough.

Location of Float-Chamber Atmospheric Vents. The pressure of the propeller blast is often an appreciable percentage of the difference in pressure in the carburetor causing fuel flow; and it is very important that whatever pressure disturbance is caused by the propeller blast should operate equally on both sides of the fuel metering jet so that the fuel flow will be responsive only to the difference in pressure resulting from the flow of air through the carburetor. To insure this condition, the float vents or mixture control openings are brought to the air entrance of the carburetor. Any pressure disturbance resulting from the propeller blast or forward motion of the ship is thereby balanced equally on the float chamber and on the fuel jet. Whatever slight depression may exist in the air entrance is transmitted to the float chamber and, for this reason, a manometer connected to the float chamber during dynamometer test may show some depression with either type of control in the full-rich position.

Float Mechanism—Normal Float Action. In an aircraft carburetor the fuel flow should be subject to no other force than the suction resulting from the air flow through the carburetor. It is therefore necessary to provide a separate constant-lever reservoir or float chamber between the main gasoline tank and the metering system of the carburetor. The action of the float mechanism is indicated in Fig. 58, which shows the design used in many Stromberg carburetors. With no fuel in the carburetor, the float takes the position shown by the dotted lines, leaving the needle valve open. As fuel is admitted from the supply line, the float rises and closes the valve as the fuel reaches the lever indicated by the dotted line. When the engine is running and fuel is being drawn out of the float chamber to the jets, the valve does not alternately open and close but takes an intermediate position such that the valve opening is just sufficient to supply the required amount of fuel and keep the level constant. This running level is usually about $\frac{1}{8}$ inch below the standing level, and the vibration keeps the fuel splashing considerably above this level.

These float mechanisms have been designed to operate at between one and four pounds pressure, and a pressure of three pounds is recommended for service use. The float mechanism of the Series "R" carburetors will operate on the head of 24 inches of gasoline; but some of the other models, due to the space limitations of the engine, could not be designed sufficiently large to operate satisfactorily on a low gravity head. The float mechanisms of Stromberg carburetors will withstand a pressure of six to eight pounds per square inch without flooding, the engine not running.

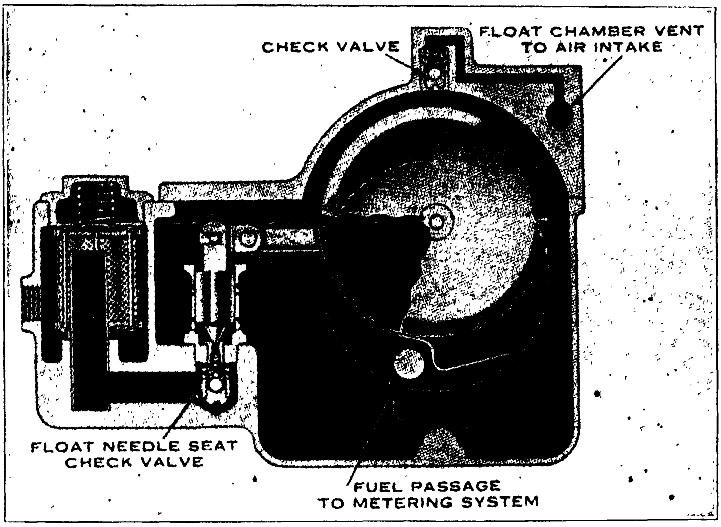

CHECK VALVE
FLOAT CHAMBER VENT TO AIR INTAKE
FLOAT NEEDLE SEAT CHECK VALVE
FUEL PASSAGE TO METERING SYSTEM

Fig. 58. Typical Stromberg Float Mechanism Construction

Float Action During Maneuvers. The operation of the float mechanism and the position of the fuel during different maneuvers of the airplane depend not only upon gravity but also upon the motion and position of the airplane. The motion of the airplane involves inertia and during certain movements centrifugal force, while the position of the airplane determines the position of the outlets from the float chamber relative to the earth. It is necessary that the float mechanism should operate positively at all angles and positions where power is demanded from the engine and that it should not permit leakage of gasoline in other positions.

Figs. 59, 60, 61, 62, 63, and 64 show the approximate position of the fuel in the float chamber during normal level flight and during some of the commonly executed maneuvers. The pilot and passengers are acted upon by the same forces that affect the fuel in the carburetor. If the pilot is resting on the seat, forced to lean hard

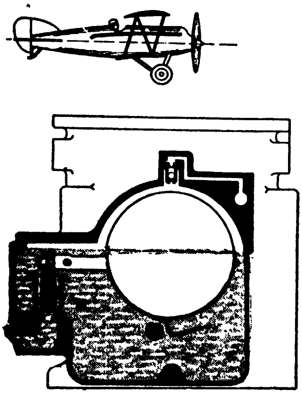


Fig. 59. Level Flight—Normal Feed to Jet and Normal Float Action

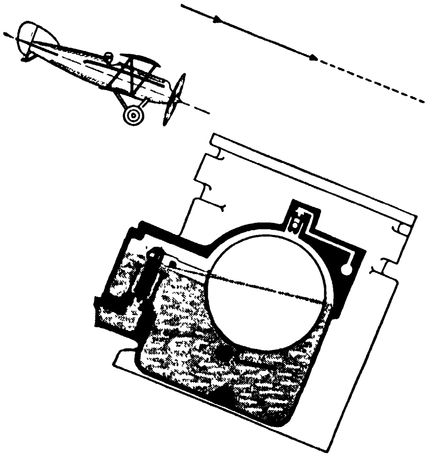


Fig. 60. Dive—Normal Feed to Jet

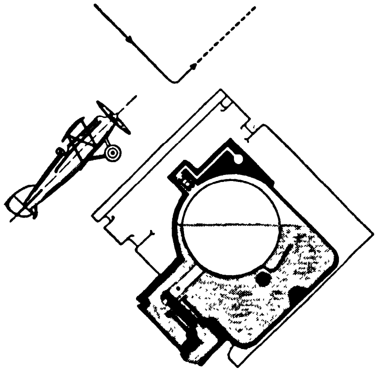


Fig. 61. Zoom Following Dive on Continuous Steep Climb—Normal Feed to Jet

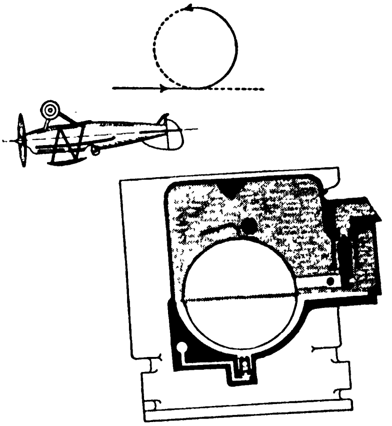


Fig. 62. Loop without Stall—Normal Feed to Jet

against the back or sides of the seat or tending to slide forward, the float action will be normal although the fuel will shift in the same direction. These conditions exist in a climb, dive, side slip, skid, barrel roll, or a loop executed without stalling, as indicated by Figs.

59 to 62. It will be noted from these illustrations that the passage leading to the metering system is always covered with fuel so the fuel feed to the engine is not interrupted.

If the position or motion of the airplane is such that the pilot tends to be lifted off the seat and be supported by the belt, the same forces will cause the fuel to go to the top of the float chamber. This can occur when a violent gust of wind forces the airplane down so quickly that the pilot leaves his seat. In such case, the fuel will take the position shown in Fig. 63. It also occurs, and for a much longer period of time, when the airplane is flown upside down. The float action is then reversed and the needle valve is held open as shown in Fig. 64. Although the fuel is forced to the top of the float chamber, the outlet to the metering system is not uncovered. If the engine is fitted with a fuel pump which is supplied with fuel in the inverted position, the fuel line pressure is exerted on the metering system and an excess amount of fuel may be supplied to the engine. This excess is prevented in some designs by the use of a check valve incorporated in the needle valve seat, as shown in Fig. 58, and these carburetors function in the inverted position so the engine will continue to run at full throttle. The design of some of the older models is such that

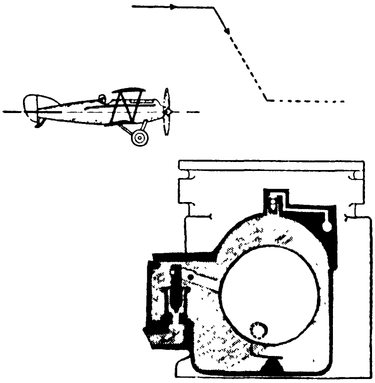


Fig. 63. Air Pocket a Start of Dive
Float action reversed. Normal feed to jet of gravity fuel system or check valve on needle valve seat are used.

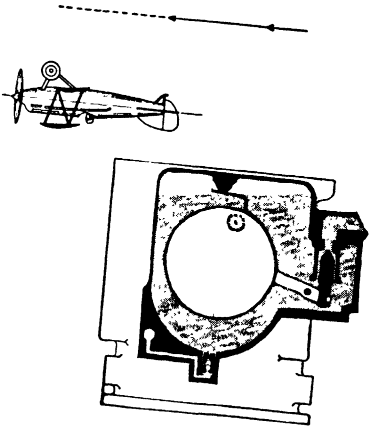


Fig. 64. Upside Down Flight
Float action reversed. Continuous feed to jet if fuel pump is used.

the needle valve is closed in inverted flight and thus cuts off the supply of fuel to the engine.

In older aircraft carburetor practice, the carburetor barrels and fuel discharge nozzles were located ahead of or behind the float chamber. With such an arrangement, when standing with tail down or diving at a steep angle, the main jet was considerably above or below the fuel level. When above, there was a tendency for the mixture to be unduly lean; when below, there was a tendency for the fuel to leak out. In the newer Stromberg types, the fuel discharge nozzles are located in line laterally with the center of the float, with the result that the fuel flow is not disturbed in any normal flying position.

In all of the "Y"-type carburetors and in the "NA-T4B," two floats are used, both attached to the same lever and float needle valve, one ahead of and one to the rear of the fuel discharge jet. As the carburetor is inclined, the fuel level rises on one float and goes down on the other but its position with reference to the discharge nozzle is not changed.

Fuel Strainer. In most models the fuel supply first enters a strainer chamber where it must pass through the strainer screen, which intercepts any dirt particles which might clog the needle-valve opening or later the jets. The strainer is retained by a strainer plug or a compression ring and can be easily removed when the strainer plug is taken out. By removing the strainer, the strainer chamber can be thoroughly drained and flushed out.

Float Needle Valve. The float needle-valve parts in an aircraft carburetor are subject to a severely destructive effect from the engine vibration. Their design and the selection of the materials used has therefore received very careful consideration. The needle-valve seat and float lever pin are of hard Monel metal, while the needle point is made of an even harder noncorroding alloy steel. This graduation in hardness is used in order that the unavoidable wear may be confined to the seat, so that it will tend to conform to the shape of the needle.

Fuel Level. The level reached by the fuel in the float chamber depends somewhat upon the specific gravity of the fuel used, being slightly higher as the fuel is lighter, and also upon the pressure or fuel head at the carburetor inlet. As set at the factory, these float valves will operate properly and hold the level sufficiently close, with fuels ranging between 58 and 76 degrees Baume gravity, specific gravity .745 to .679. Alterations in the level are obtained by the use of thicker or thinner gaskets under the needle-valve seats.

Main Metering System. The main metering system controls the fuel feed in the upper half of the engine speed range, as used for cruising and full-throttle operation. This system consists of a metering jet through which the fuel is drawn from the float chamber; a main discharge assembly (two types of which are used); a passage leading to the idle system. The metering jets are of a standard type and are numbered to indicate the size, the numbers ranging according to the twist drill and steel wire gauge.

Main Discharge Assembly. Two types of main discharge assembly are used, as shown in Figs. 65 and 66. In the construction shown in Fig. 65, three pieces are used—the main discharge nozzle, the main discharge nozzle stud, and the main discharge nozzle screw. The main discharge nozzle, which is usually an aluminum casting, provides an air-bleed opening behind the venturi and the fuel emulsion discharge holes located at the center of the venturi so as to spray this emulsion evenly through the column of entering air. The main discharge nozzle stud is threaded into the main discharge nozzle and has a center hole or passage in which the fuel from the metering jet and the air from the air bleed mix to form an emulsion, the air entering through side holes. The size of the center hole should bear a definite relation to the amount of fuel and air which must pass through it. If this passage is too large the air bubbles will not fill it to give a homogeneous emulsion; if it is too small, the

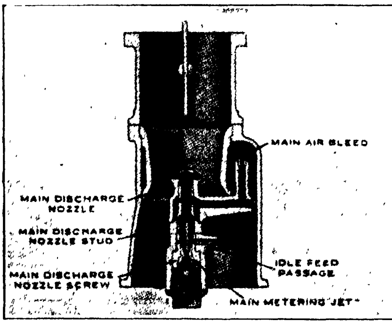


Fig. 65. Three-Piece Main Discharge Assembly

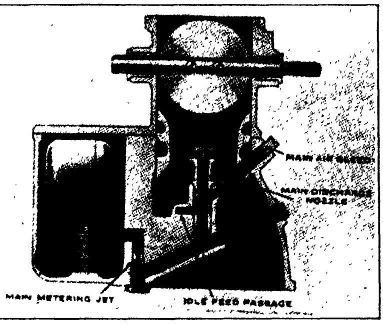


Fig. 66. Main Discharge Assembly as Used on Series "R" Carburetors

resistance to flow at high speeds will retard the flow of this emulsion more than it does the air, resulting in a tendency toward a lean mixture at high speed.

The center hole of the discharge nozzle is considerably larger than the outside diameter of the discharge-nozzle stud, thus forming an annular space, called the accelerating well. The holes drilled in the tubular wall of the emulsion passage connect this passage with the accelerating well. The upper holes are near the fuel level and are uncovered at the lowest suctions that will draw fuel from the main jet, so that they admit air to the emulsion passage all the time the main jet is in operation.

The lower holes into the emulsion passage furnish the desired area of opening for the fuel to pass from the accelerating-well chamber to the emulsion passage for acceleration. They are usually made of aggregate area equal to or greater than the emulsion passage so that when the throttle is opened, the accelerating well may discharge as promptly as possible.

The volume of the accelerating-well chamber has been worked out experimentally on the different carburetor models so that the excess volume of gasoline discharged when the throttle is opened will give smooth and positive acceleration under ordinary operating conditions.

The size of the holes in the sides of the emulsion passage determines to a certain extent the size of the air bubbles formed inside the jet, and it has been found that the smaller size holes give a finer emulsion and a steadier flow. For this reason, a number of small holes are used rather than fewer large ones.

The main discharge nozzle screw is threaded into the main discharge nozzle stud and is used to hold the assembly in the discharge nozzle boss, which is a part of the main body casting. Idle feed holes are drilled in this screw to connect the lower end of the emulsion passage with the passage leading to the idling system. The total area of the holes is considerably larger than that of the idle metering jet, so they cause no restriction.

In the main discharge assembly, shown in Figs. 66 and 67, the functions of the main discharge nozzle and the discharge nozzle stud have been combined in one piece, screwed directly into the discharge nozzle boss, which is a part of the main body casting. This eliminates the necessity of having a discharge nozzle screw. The air bleed is a brass tubular part screwed directly into the discharge nozzle boss. This type of construction is used in carburetors which have an accelerating pump to supply the necessary additional fuel for acceleration, and the accelerating well space is therefore made small and acts as a passage for the air bleed. The idle feed passage is located near the bottom of this space. The fuel from the metering jet mixes with the air from the air bleed to form an emulsion in the bore of the discharge nozzle. The operation, with this exception, is practically the same as that of the three-piece construction.

Pulsation Control Nozzle. At full open throttle and full speed, air flows back into the main discharge passage from the idling system, and this has a tendency to make the mixture leaner than if such air flow or air bleed were not taking place. This tendency is least when the air from this source comes in with the main air bleed at about the level of the lower rim of accelerating-well feed holes, as shown in Fig. 65. Due to the effect of pulsations with three or fewer cylinders pulling from one carburetor air opening, the suction on the main metering system is higher in proportion to the air flow at wide-open throttle than at part throttle, so that from this cause there may be a tendency to give too rich a mixture at full throttle if the metering jet size has been selected to give the correct mixture for part throttle operation. The leaning-out effect of the reverse air bleed through the idle system at wide-open throttle may then be utilized to counteract this pulsation effect by the construction shown in Fig. 68. This illustrates the type of main discharge system used in the "NA-Y5F" and the "NA-Y60" carburetors as fitted to the Curtiss "D-12" and "Conqueror" engines. In this jet form, the channel carrying the idle feed holes is made small in diameter, which increases the "leaning-out" effect of the reverse idle air bleed. It is found that if the correct size metering jet be selected for part throttle or cruising speeds, say from 1,600 to 1,900 revolutions per minute, with a propeller which permits a maximum engine speed of 2,000 revolutions per minute, that without disturbing the mixture setting in the part throttle range, the mixture at 2,000 revolutions per minute can be varied by proper selection of the size of this passage. The smaller the passage is made the leaner is the mixture at full speed.

Idling Metering System. During the lower half of the engine speed range, the suction on the main discharge jet is very low, scarcely sufficient to lift fuel from it. At the same time, however, there is a very high suction on the intake manifold side of the throttle and the fuel feed is, therefore, arranged to deliver into this region of high suction. To utilize this suction, a complete discharge jet system in miniature is used with fuel metering jet, air bleed, and discharge jet opening into the small air passage around the throttle formed by the slot in the idling discharge jet.

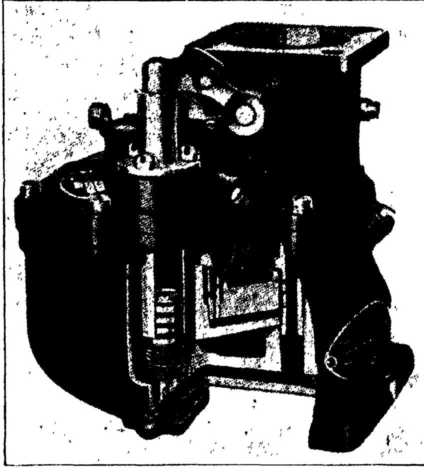


Fig. 67. Sectioned View of "NA-R5A" Carburetor, Showing Accelerating Pump, Idle Tube, and Main Discharge Nozzle

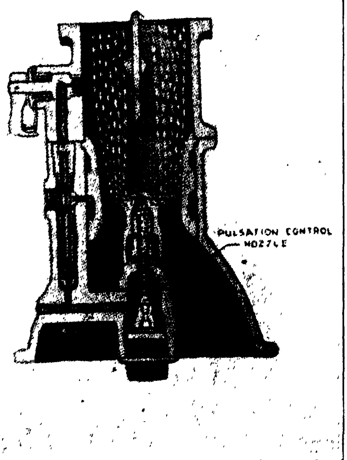


Fig. 68. Pulsation Control Nozzle Construction to Counteract Enrichment Caused by Pulsating Air Flow

The method of mixture graduation on this small carburetor element is entirely different from that of the large one, for the reason that the greatest suction in the intake manifold above the throttle is at the lowest speed when the least air is being taken in and consequently when the least fuel is needed. As the engine speed increases and more fuel is needed, the suction in the manifold diminishes. To overcome this difficulty, the idling fuel system does not meter under the suction existing in the intake manifold but instead is controlled by the suction existing in the small intermediate chamber or slot formed by the idle discharge nozzle and the wall of the carburetor at the edge of the throttle valve and having openings into the barrel both above and below the throttle. Fig. 69 illustrates the construction used, *N* indicating the position of the throttle valve at approximately 400 revolutions per minute (propeller load), and *M* the position at 600 revolutions per minute. The air opening around the throttle in the carburetor barrel, required by the increased engine speed, is approximately 50 per cent greater at *M* than at *N*. When the throttle is in the position *N*, the exposed opening of the idling slot toward the venturi tube is considerably larger than that toward the intake manifold and the suction at the idle discharge nozzle orifice is more nearly the low suction existing in the venturi than the high suction in the intake manifold. When the throttle has taken the position *M* for 600 revolutions per minute of the engine, the suction at the discharge nozzle is higher than before, as the openings to the intake manifold and to the venturi side of the throttle valve are about equal and the suction at the discharge nozzle is about the average of those above and below it. At 900 revolutions per minute, the throttle will have opened still further so that all of the discharge nozzle is in communication with the intake manifold and the suction will be higher even though the suction in the intake manifold is lower than it was at lower speeds. By having this increase in suction on the idling system properly graduated, the correct fuel feed can be maintained throughout the low speed range.

Idling Adjustment. While the throttle edge is directly in front of the idling discharge nozzle, the mixture is controlled by the amount of opening above and below the throttle edge (idle discharge nozzle position). The idle metering jet size, the idle air bleed size, and any of these may be varied to give the adjustment. Adjustment of the idle air bleed or idle metering jet affects the entire low-speed range about equally, from the lowest idling speed to about 900 or 1,000 revolutions per minute. For this reason, these variables are made of fixed size to suit the engine requirements, and the idle adjustment is obtained by rotating the idle discharge nozzle to expose more or less area above the throttle edge, there being a lever and a quadrant on the outside of the carburetor to show the range of adjustment. With this type, the effect of the adjustment is the greatest at very low speeds and disappears entirely at 600 to 700 revolutions per minute. A convenient means of setting for speeds from 650 to 900, without affecting either the low idle or high speed, is afforded by selection of the proper idle air bleed size—a larger bleeder making the mixture leaner and a smaller one richer.

The idle metering orifice is usually located in the lower end of the idle tube, but in some models it is in a separate part or jet, which is screwed into place. The tube or jet must seat securely, otherwise the effect of a larger idle metering orifice will be obtained, resulting in a richer mixture at low engine speeds and a leaner mixture, due to the larger reverse air bleed into the main jet, at full throttle.

Operation of Carburetor. Figs. 70 to 73 indicate the operation of a carburetor with the accelerating-well type of main discharge system by showing the position of the fuel and the functioning of the air bleed at various throttle positions. The carburetor is shown in diagrammatic form without regard to the actual details of mechanical construction.

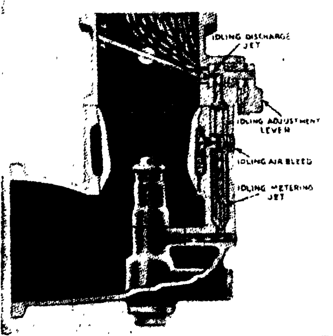


Fig. 69. Typical Idling Metering System

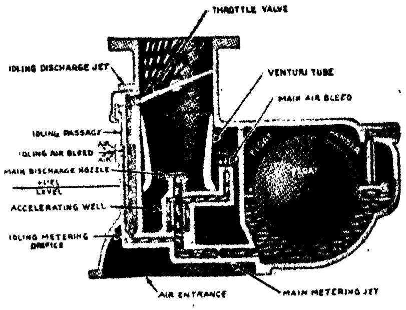


Fig. 70. Engine Starting

Fig. 70 shows the condition when starting. The suction caused by turning the engine draws fuel from the idle well through the idle tube into the carburetor barrel. No air is mixed with this fuel in the idle system under these conditions.

As soon as the engine starts, air is bled into the idle tube through the holes near the lower end, as shown in Fig. 71, and this emulsion is drawn out the idle discharge nozzle in a fan-shaped spray. The accelerating well, it will be noticed, is nearly full.

As the throttle is opened, the suction on the main discharge nozzle increases until fuel is drawn out and the main air bleed starts to function, as shown by Fig. 72. This shows the position of the fuel and emulsion in the main and idle system at about 900 to 1,000 revolutions per minute, with fuel being supplied by both systems. The accelerating well is now partly emptied but still contains sufficient fuel for satisfactory acceleration if the throttle is opened quickly.

Fig. 73 shows the action at full throttle with all of the fuel being supplied by the main system and air being drawn in through the main air bleed and the idle system. The accelerating well is empty.

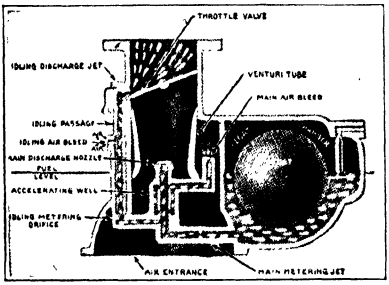


Fig. 71. Engine Idling

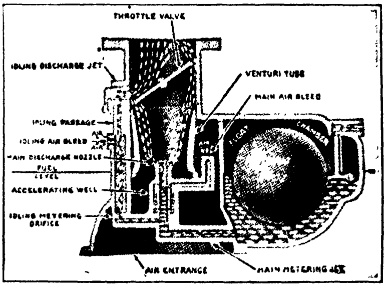


Fig. 72. Throttle Partly Open. Giving about 900 R.P.M.

Main discharge jet and idling discharge jet are both in operation. Accelerating well is partly emptied.

Accelerating System. A temporary enrichment of the mixture is required to obtain smooth and positive acceleration when the throttle is opened quickly.

Accelerating Well. At idling speeds, very little throttle opening is required and the vacuum in the intake manifold is relatively high. If the throttle be opened suddenly, air will be drawn in not only to supply whatever cylinder may be on the suction stroke, but also to fill the intake manifold. This quick rush of air temporarily creates a high suction at the main discharge nozzle, brings the main metering system into operation, and draws the fuel from the accelerating well. The engine speed then increases, due to the throttle opening and the main system continues to function.

Accelerating Pump. The accelerating pump used in these carburetors is of a new and exclusive Stromberg construction and possesses the advantages of giving a positive and definite accelerating charge, regardless of the suction existing in the carburetor. It delivers this charge as a momentary spurt of fuel, followed by a sustained discharge lasting several seconds. As shown by Fig. 74, this consists of an inverted cylinder having a stem at the upper end which is operated by the throttle. Within the cylinder is a piston, which slides on a hollow stud screwed into the main body casting. The upper end of this stud is shaped like a small poppet valve with several holes in the wide face of the valve leading into the center hole. The valve seat is in the piston, which is held up against the valve by the pressure of a spring. The center hole of the stud connects with a passage leading to the main discharge nozzle, and the whole assembly is mounted in the float chamber. Figs. 74, 75, and 76 show the relative positions of these parts under several conditions of operation. When the throttle is closed and the cylinder is in the top position, the space within the cylinder is filled with fuel, Fig. 74. As the throttle is opened rapidly, the cylinder is moved down and the pressure of the fuel above the piston forces it down, thus opening the valve so that fuel under pressure is forced out the main discharge nozzle, Fig. 75. The spring then forces the piston up so the fuel discharge continues even after the throttle has reached the wide-open position. If the throttle remains open, the piston soon reaches the valve seat and stops all fuel flow through the accelerat-

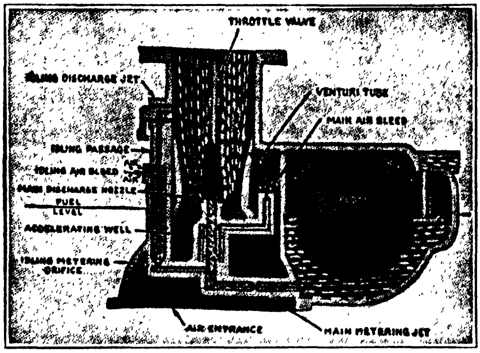


Fig. 73. Full Open Throttle
Accelerating well space is empty. Note air entering base of main discharge nozzle through idling metering orifice.

ing system, Fig. 76. As the throttle is closed, fuel is drawn into the cylinder through the clearance space between the piston and cylinder. This arrangement of filling the cylinder provides automatic regulation of the fuel charge, depending upon the speed of throttle opening. If it is opened slowly, the fuel passes through the clearance space back into the float chamber and the engine receives no accelerating charge, whereas the maximum speed of throttle opening gives the maximum accelerating charge. For use on engines which require a large accelerating charge for cold weather operation only, a restriction or reducer may be used to reduce this charge of fuel during warm weather operation. This arrangement makes it possible to obtain smooth and positive acceleration under all conditions of operation without changing the metering characteristics of the carburetor. Details of the pump construction are shown in Fig. 77.

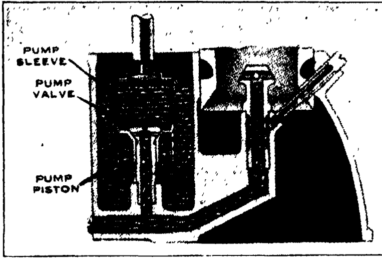


Fig. 74. Idling
Closed throttle, sleeve at top of stroke, piston seated.

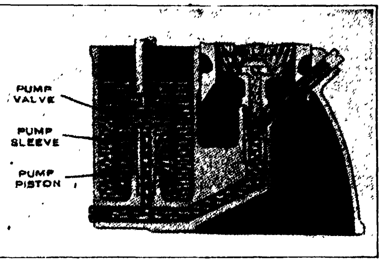


Fig. 75. Just after Opening Throttle
Full throttle sleeve at bottom of stroke, piston off seat, accelerating fuel being discharged.

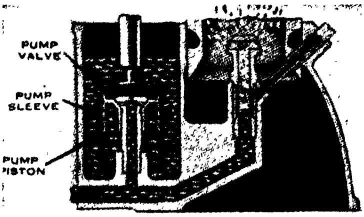


Fig. 76. Full Throttle
Sleeve at bottom of stroke, piston seated.

Economizer System. *Needle-Valve Type.* The needle-valve type of economizer is shown in Fig. 77. This is of a very simple construction, consisting of a needle valve held on a needle-valve seat by means of a spring. The entire assembly is located in a well, which is kept filled with fuel from the float chamber by an opening located about midway between the fuel level and the bottom of the float chamber. Immediately below the needle-valve seat is a metering jet. With the needle seated, no fuel can flow through the economizer system; but as the needle is lifted off the seat, fuel is drawn past the needle through the economizer metering jet into a passage leading to the main discharge nozzle. A forked lever is fitted to the throttle shaft in such a way that, as the throttle is opened, the fork engages an adjustable nut on the upper end of the needle valve stem and raises the needle off its seat. The throttle position at which the economizer needle is lifted depends upon the position of the nut on the economizer stem. This varies slightly for different types of engines but is usually set for a throttle opening of 25 to 30 degrees, which corresponds to an engine speed of approximately 200 revolutions per minute less than the full throttle engine speed.

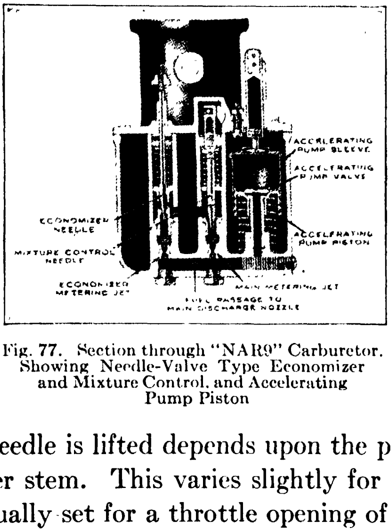


Fig. 77. Section through "NAR9" Carburetor. Showing Needle-Valve Type Economizer and Mixture Control, and Accelerating Pump Piston

Poppet Valve. On some carburetor models, a poppet valve is used in place of the needle valve. This type of valve is opened by an arm fastened to the accelerating pump stem, which is operated by the throttle. The arrangement of the economizer jet and the passages is the same as with the needle type of valve.

Piston Type. The economizer used on the "NA-Y7A" and "NA-Y7B" carburetors is of the piston type and, in addition to furnishing a rich mixture at full throttle, provides an extra fuel supply for acceleration when the throttle is opened quickly. The position of the economizer piston at idling, part throttle, and at full throttle, as well as the general arrangement of the fuel and air passages of the "NA-Y7B" carburetor, is shown in Figs. 78, 79, and 80.

The fuel enters the economizer from the float chamber through the economizer metering jet *A*, Fig. 78, which serves to meter the fuel passing through the economizer system. By changing the size of this jet, the amount of maximum economizer action is regulated.

The fuel, after passing through this jet, flows up the passage *B* and across to the economizer proper. It enters the economizer through the port *C*, filling up the economizer well space *D* and the passage *E*, so that the level in *E* is the same as that in the float chamber, as shown in the illustration.

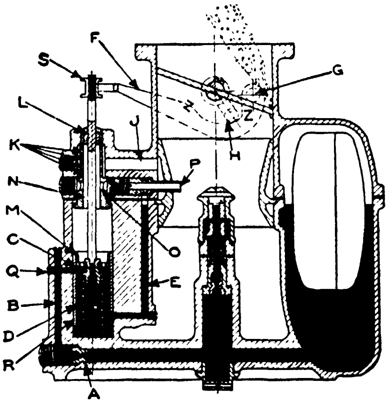


Fig. 78. Piston Type Economizer at "Idling" Position

The economizer proper consists of two pistons *L* and *M*, working in a sleeve *N* and a bushing *R*. The upper piston *L* works to regulate the air bleed to the economizer, while the lower piston *M* operates on the fuel flow. The air bleed at practically atmospheric pressure enters the passage *J* from behind the venturi, and passes through the ports *K*, *K*, *K*, etc., to the interior of the economizer. It goes to the discharge nozzle *P* through the common fuel and air passage *O*. This air bleed serves to relieve the suction existing at part throttle so that the fuel will not be drawn past the piston *M* (clearance must be allowed for the operation of the piston) or through the passage *E*.

As the throttle is opened, the economizer moves downward, being actuated by the cam lever *F* which is pivoted at *G* and operated by the lever and roller *H*, directly connected to the throttle valve stem. At intermediate throttle positions, the piston *M* has moved downward until it covers the port *C*, as shown in Fig. 79. With the piston in this position, the throttle is open sufficiently to admit a No. 51 drill between the throttle edge and the barrel. It will be noted that the piston *L* has not moved downward enough to close off the air flow to the economizer.

As the throttle is opened, the economizer is moved farther downward until at wide open throttle the position shown in Fig. 80 is reached. The fuel flows through the hole *C*, straight up the economizer and out the discharge nozzle. The piston *L* now covers the air ports *K*, *K*, etc., so that the suction on the economizer system is at a maximum. The clearance between the piston *L* and its guide is great enough so that there is a small air leakage past the piston. This air mixes with the fuel at *O* so that an emulsion of air and fuel issues from the nozzle *P*. The fuel flow through the economizer system starts when the upper edge of piston *M* passes the edge of the passage *C*. This corresponds to a throttle opening of 22 degrees. As the throttle when closed forms an angle of 20 degrees with the carburetor flange, the angle between the throttle and flange will be 42 degrees when the economizer action starts.

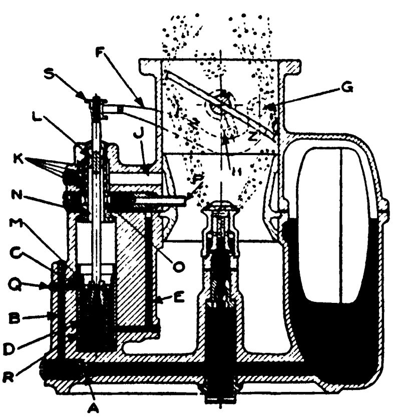


Fig. 79. Piston Type Economizer at "Part Throttle" Position

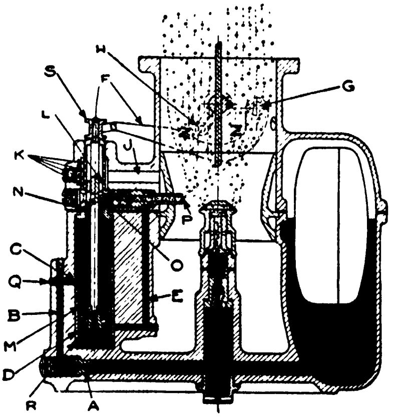


Fig. 80. Piston Type Economizer at "Full Throttle" Position

Previously the action of the economizer has been considered only at fixed throttle positions. As the piston *M* moves downward, the check valve is closed and the fuel in the space *D* is forced out and up the passage *E*, discharging through the nozzle *P*. This provides an accelerating charge which insures instantaneous operation regardless of the speed of throttle opening.

The nozzle *P* is so designed that the accelerating charge of fuel enters from an annular groove and is directed toward the venturi by several holes drilled at an angle between this groove and the center hole of the discharge nozzle. This arrangement prevents the fuel from entering the space above the piston *M* during a rapid opening of the throttle.

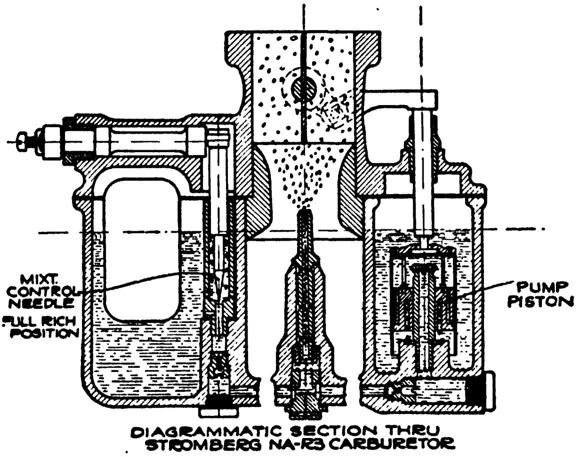


Fig. 81 Combined Economizer and Accelerating Pump

Combined Economizer and Accelerating Pump. The economizer, as used on the $1\frac{1}{2}$-inch and $1\frac{3}{4}$-inch models of the "R" series, is incorporated in the design of the accelerating pump. The design of the piston is, however, slightly different from that used in other carburetors of this series, as will be noted by a comparison of Figs. 74 and 81. As the throttle is opened, the pump sleeve is moved down and the sleeve strikes two pins on the pump piston so that further opening of the throttle forces the piston down, thus opening a valve and allowing fuel to flow from the space above the piston into a passage leading to the main discharge nozzle. An annular groove on the outside of the piston registers with holes in the sleeve when the sleeve strikes the pins. Holes drilled from the top of the piston into this groove allow fuel to flow from the float chamber into the space above the piston. The sleeve strikes the pins at a throttle position, which gives about 200 revolutions per minute less than the full throttle revolutions per minute. On later models these pins are omitted, and the same action is obtained by a groove spun in the pump sleeve, which strikes the top of the piston.

Needle Valve. Fig. 82 shows the construction of the needle-valve type of mixture control used on the "NA-R7" and "NA-R9" carburetors, Figs. 83 and 84, and on the other models of the "R" series with slight detail changes. The needle valve and seat are in series with the main metering jet between the float chamber and the main discharge nozzle so that as the needle is lowered into its seat, the fuel flow through the main metering system is reduced. The needle is operated by an eccentrically located pin in a shaft to which the mixture control lever is fastened. This shaft is provided with a packing gland near its outer end to prevent fuel leakage when the carburetor is in an inverted position. In the full-lean position, the needle should touch the seat. In the full-rich position, the needle is raised off the seat. The area around the needle in the full-rich position is larger than the area of the metering jet, so that the size of the metering jet determines the quantity of fuel passage through the main metering system.

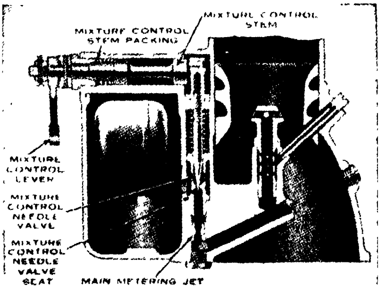

MIXTURE CONTROL STEM
MIXTURE CONTROL STEM PACKING
MIXTURE CONTROL LEVER
MIXTURE CONTROL NEEDLE VALVE
MIXTURE CONTROL NEEDLE VALVE SEAT
MAIN METERING JET

Fig. 82. Needle Valve Type of Mixture Control as used on Series "R" Carburetors

Back-Suction Type. Fig. 85 shows the details of construction of the back-suction type of mixture control as used in the "NA-Y7B" carburetor. The suction nozzle is located above the throat of the venturi and is connected to the space above the flat disc valve. A large passage leads from the opening in the valve to the air intake of the carburetor so that, when operating at cruising or full-throttle speeds, there is a flow of air through the mixture control chamber but not through the float chamber. The mixture control chamber

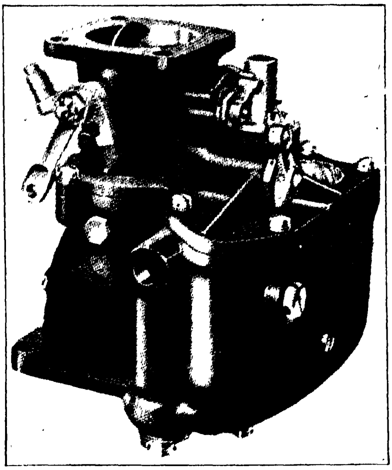


Fig. 83. Stromberg "NA-R5A" Carburetor

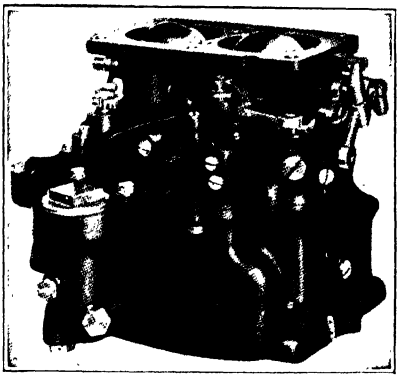


Fig. 84. Stromberg "NA-Y7" Carburetor

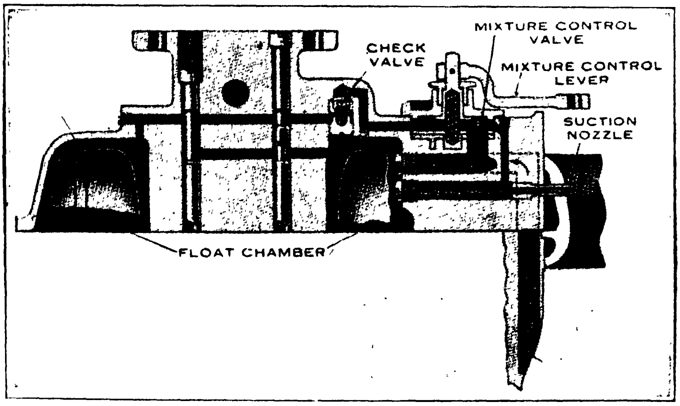


Fig. 85. Diagrammatic Drawing of Back of Suction Type of Mixture Control

is connected to the float chamber through several passages and a check valve. This valve is open during ordinary flying but closes when the airplane is flown upside down or during maneuvers which tend to lift the pilot off the seat, and thus prevents fuel from flowing into the mixture control system and making the mixture excessively rich. The method of venting the two float chambers together is used to prevent fuel getting into the mixture control system during certain maneuvers.

CARBURETOR SERVICE INFORMATION

Installation. There are many factors affecting satisfactory carburetor operation in service which cannot be cared for in carburetor design alone. A recognition of the requirements regarding tanks, fuel lines, fuel pressure at the carburetor, controls, the application of heat to the induction system, and the effect of rapid acceleration in maneuvers and catapulting must be had if the carburetor is to function successfully in the airplane.

Fuel Tanks and Lines. The tanks and fuel lines must be so located that there is no tendency for an air lock to form in the lines and obstruct the fuel flow. The forces due to rapid acceleration in maneuvers and in catapulting are often greater than that of gravity, with the result that the fuel shifts in the carburetor and tanks with consequent changes in fuel level. The carburetors are so designed that with these changes in level, fuel will always flow to the metering system. The flow of fuel to the carburetor must also continue at a normal rate if it is to continue to function. The location of the tanks and their fuel outlets should, therefore, be so related to the carburetor that no interruption of fuel supply takes place under these conditions.

Fuel Pressure. The fuel pressure at the carburetor should be sufficient to maintain a normal level of fuel in the float chamber of the carburetor. On some of the models the space limitations were such that small float mechanisms had to be used, and on these a pressure fuel system must be used. A fuel pump is usually used with these carburetors and a fuel pressure of three pounds per square inch at the carburetor inlet is recommended. This corresponds to a fuel head of 117 inches of gasoline at .710 specific gravity. Other models, including all of the "NA-R" series, may be used with a gravity system, and a minimum fuel head of 24 inches is recommended. Under certain special conditions a lower head may be used, but this should be taken up with the Stromberg Motor Devices Company before an installation is made.

Carburetor Mounting. The carburetor should always be so mounted on the engine that the fuel level at the discharge nozzle will not be changed during a climb or a dive. On the single-barrel models this requirement is fulfilled if the carburetor is mounted with the float chamber at the side. The "NA-Y" models should be mounted with the float chamber fore and aft of the barrels, and the "NA-U" models with the barrels at the sides of the float chamber.

Heat Application. The vaporization of fuel in the carburetor barrel and in the manifold above the carburetor is accomplished through the flow of heat from the surrounding metal into the fuel. Unless heat is supplied to the manifold or the entering air, the temperature will drop to a very low value and will interfere with vaporization and, under certain atmospheric conditions, will cause a formation of ice in the induction system. This ice formation constitutes a serious danger and may be sufficient to cause loss in power and rough running of the engine. The manifold immediately above the carburetor should, therefore, be heated with water, oil, or exhaust gas. Practically the same results may be obtained, although the temperatures must be higher, by heating the inlet air passing to the carburetor.

Controls. The control rods and levers used to operate the throttle and mixture control should be of rugged construction so that positive operation may be obtained. The use of flimsy wire controls is not recommended. The system should be so designed and built that full movement of the carburetor control levers is obtained and that the movement is in the proper direction.

Starting. The best procedure to follow in starting depends to a great extent upon the starter and primer equipment furnished by the engine manufacturer, so it is impossible to give detailed rules for starting. The following comments concerning the functioning of the carburetor during the starting process should, however, facilitate starting an engine for the first time or until its starting characteristics are determined.

In turning the propeller either by hand or by a starter, the suction produced at the carburetor is relatively low and the throttle should be closed or nearly closed in order to draw fuel through the idle system into the manifold.. The idle wells in the carburetors are of the self-priming type, which is of special value when starting by hand. When the propeller is turned with the throttle closed, fuel is drawn from the idle well through the idle tube and out the idle discharge nozzle. When the operator stops turning to obtain another grip on the propeller, this well fills with fuel so that on the next turn additional fuel is drawn in. Continuous turning of the propeller does not give this action as the well is soon emptied and air is drawn into the idle tube through the idle air bleed. This priming action is sufficient for warm-weather starting, but as a rule it does not provide sufficient fuel for cold-weather conditions and the primer system on the engine should be used. If no primer is provided, the engine may be primed by squirting gasoline into the exhaust ports near the exhaust valve and then turning the propeller over in the backward direction.

After fuel has been drawn into the manifold or the primer used, the ignition should be turned on and the propeller turned by hand or by the starter, or the booster magneto should be used if one is provided. As soon as the engine starts, the throttle should be opened slightly and the engine warmed up at a speed of 700 to 900 revolutions per minute. On the "NA-R" carburetors, which are provided with an accelerating pump, the engine can be kept running by partly opening and closing the throttle quickly. This action will operate the pump and supply a rich mixture to the engine.

With a hot engine or in very warm weather, there is a possibility of getting too much fuel in the induction system. This "loaded up" condition may be overcome by turning the engine over backward or by opening the throttle to the wide-open position and turning the propeller forward, thus drawing air with practically no fuel into the induction system.

Adjustments. The metering jets controlling the fuel flow at full throttle and at cruising speeds are of the fixed type and no adjustment is required. After the engine has been thoroughly warmed up, the minimum speed operation should be made satisfactory by the regulation of the idle adjustment and the throttle stop screw. The operation at idling speed will generally be found to be best with an idle mixture amply rich. It should not be set rich enough to cause the engine to "load up" when idled for a long period of time. After making an idle adjustment, the throttle should be opened and then closed quickly to make sure there is no tendency to stop. If there is, the throttle stop should be set to give a faster idle speed. The operation of the engine at all speeds, the acceleration, and the operation of the mixture control should be checked.

Inspection in Airplane. The carburetor strainer should be removed and cleaned frequently and the strainer chamber flushed out with gasoline to remove any foreign matter or water. The fuel lines should be inspected to make sure that they are tight and in good condition. The carburetor should be inspected to make certain that all safety wires, cotter pins, etc., are in place, and that all parts are tight. On those models having economizer or accelerating pumps, the operating mechanism should be frequently cleaned and a small quantity of oil put on the moving parts.

Overhaul and Inspection. The carburetor should be disassembled for cleaning and inspection each time the engine is given a general overhaul, when there has been an accident which might have damaged the carburetor, or when its action is known to be unsatisfactory. In disassembling, the halves should be separated and sufficient parts removed to permit a very thorough cleaning and inspection of all parts and passages. In general, this will include the removal of the float mechanism, float needle valve seat, strainer, main discharge nozzle assembly, metering jets, economizer, accelerating pump, mixture control valve, and passage plugs.

Tapping the brass plugs lightly with a soft wood or rawhide mallet will aid greatly in their removal from the aluminum body. If the threads stick, apply oil and work the plug in and out as is sometimes done in a tapping operation. This will allow their removal without tearing the threads in the aluminum. Wash all parts and the aluminum castings with gasoline, and clean all passages by blowing through them with an air hose.

The parts removed should all be inspected carefully for wear or irregularities of any kind. Note the condition of the float needle valve and needle valve seat. If the needle is grooved or the sides of the needle valve or needle valve guide are worn excessively, both needle valve and seat should be replaced with new parts. See that the adjustable idle discharge nozzles are clean and that they can be freely adjusted. Check the fit of the throttle valves in the barrel and the fit of the throttle shaft in its bushings. On the double or triple-barrel models see that all of the throttles close tightly with the throttle stop unscrewed. An adjustment is provided for synchronizing the throttles on double-barrel models having parallel throttle shafts connected with gear sectors. One of the gear sectors is not pinned to the shaft but is clamped directly to it by means of a bolt and nut. Loosening this nut will allow the gear sector to be turned on the shaft and an adjustment secured. On later models of this type the gear sector, which is not pinned, is fitted over an eccentric split bushing. This eccentric bushing may be rotated to eliminate excess backlash between the gear sectors. With this type of adjustment, the gears should be set with practically no backlash when the throttles are closed. The backlash which will then exist at wide-open throttle has no effect on the operation. Examine all passages to see that they are clean.

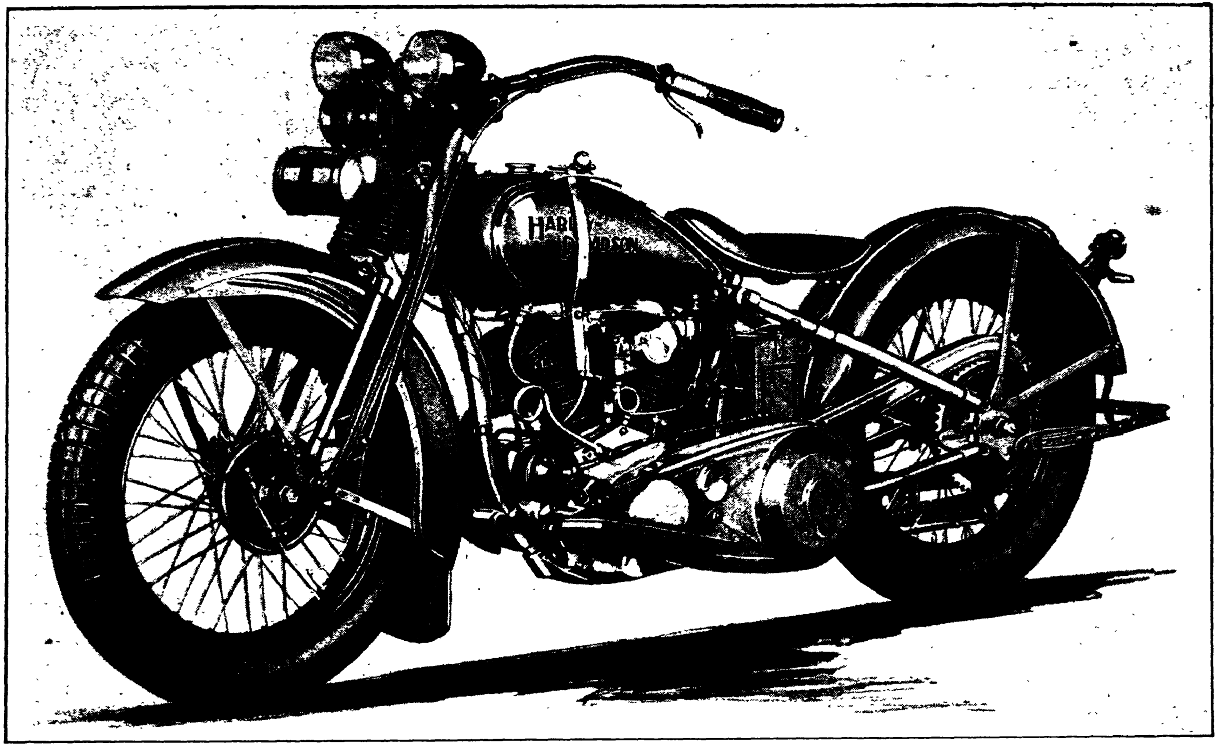
Assembly. Reassemble the parts in the lower half or main body of the carburetor, using new parts where necessary. It is very important that all gaskets be in good condition and be properly placed. Brass plugs screwed into aluminum have a tendency to stick after a long period of service, but this trouble can be obviated by the application of a thin coating of a mixture of powdered graphite and castor oil to these threads.

The needle valve and seat should be checked for leakage by holding the needle valve with the point up and the seat in place and filling the small space above the needle with gasoline. If any leakage is evident, the needle valve should be lapped in with crocus powder. If the leakage cannot be stopped in this way, a new needle and seat should be used.

After assembling the lower half of the carburetor, move the float up and down to see that it works freely and inspect it to see that it does not strike the sides of the float chamber. Check the float level by holding the lower half in a level position either on the bench or in a vise and connecting the fuel inlet to a fuel supply tank. Measure the distance from the level in the float chamber to the parting surface. This measurement should check with that given in the detail instructions on the model being tested. In the case this information is not available, the level should be set $\frac{1}{8}$ inch to $\frac{3}{16}$ inch below the bottom of the main discharge nozzle holes.

The fuel used and the height of the fuel supply tank above the carburetor fuel inlet should correspond to the conditions actually encountered in service. If the carburetor is used on an airplane having a gravity fuel system, the float level should be set with a fuel head equal to the average height of the fuel in the tanks of the airplane above the carburetor inlet. If the carburetor is used with a pressure fuel system, a pressure of three pounds per square inch or 117 inches of fuel at .710 specific gravity should be used. In case the level is not correct, adjustment should be made by changing the thickness of the gaskets under the float needle valve seat. In general, a change of $\frac{1}{64}$ inch in gasket thickness will cause a change of $\frac{5}{64}$ inch in the level. In order to lower the level, it is necessary to reduce the gasket thickness on some carburetors and increase it on others, depending on the location of the needle valve above or below the float bracket and on the location of the pivot between the float and needle valve or at one end of the float bracket. Whether to add or remove gaskets is easily determined, however, by an examination of the float mechanism construction.

The setting in the carburetor should correspond to the setting shown on the aluminum tag riveted to the casting unless there is a definitely known reason why it should be otherwise. The individual instruction sheet, usually supplied in the engine instruction book, should be consulted for detailed information concerning each individual model. Assemble the main and throttle valve bodies and safety wire all screws, plugs, etc.



HARLEY-DAVIDSON TWIN—MODEL "VL," 1930 HIGH EFFICIENCY RICARDO HEAD MOTOR, DEVELOPING 30 HORSEPOWER AT 4000 R.P.M.

This motorcycle has 74 cubic inches displacement. It is used for police, commercial, and very fast solo road work.

MOTORCYCLES

MOTORCYCLE MECHANISMS

Before going into a discussion of engines and how to take care of them, it is best to make sure that the reader understands the names and purposes of the various parts that go to make up the complete machine. When dealing with the principles of the internal-combustion engine, we always deal with the single-cylinder type for the sake of simplicity, pointing out that in the two-cylinder and four-cylinder engines there has been but a combination of several single-cylinder engines.

Referring to Fig. 1, at *A* is the cylinder casting, which is made of gray cast iron although in some cases it does not look it owing to methods of sand blasting, enameling, etc. The cooling ribs are cast integral and are not of a different material shrunk on as was tried on some air-cooled automobile engines. At *B* is the crank case, which is an aluminum casting, usually highly polished. Most automobile crank cases are split along a horizontal plane, but the motorcycle crank case is divided in the vertical plane and bolted together as shown. Piston, connecting rod, and flywheel assembly is shown at *C*. The piston moves up and down in the bore of the cylinder. It is usually made of cast iron and often drilled with a number of comparatively large holes to decrease its weight and also to assist in the lubrication of the cylinder wall. Aluminum is gaining in favor as a piston material because of its light weight. The purpose of the connecting rod is to change the back and forth or reciprocating motion of the piston into rotary motion at the crankshaft. This means that there are bearings at both ends. At the upper end, the bearing is called the wrist-pin bearing because the small shaft across the piston is called the wrist pin. At the lower end, the bearing is known as the connecting-rod bearing and the big-end bearing.

One of the main differences between the general design of the motorcycle engine and that of a small marine or an automobile engine is in construction. In the ordinary design, a one-piece crankshaft, as at *D*, is used and this extends through the crank case with the single flywheel *E* fastened on the outside, as in the Motor Wheel and in the Indian Light Twin. In all other motorcycle designs in this country however, enclosed flywheels are used. In this case there is a flywheel, on each side, as shown at *F*, these being housed inside the crank case. The counterweights to balance the inertia forces of the piston are cast as part of these flywheels instead of being fastened on, as is sometimes done with automobile crankshafts.

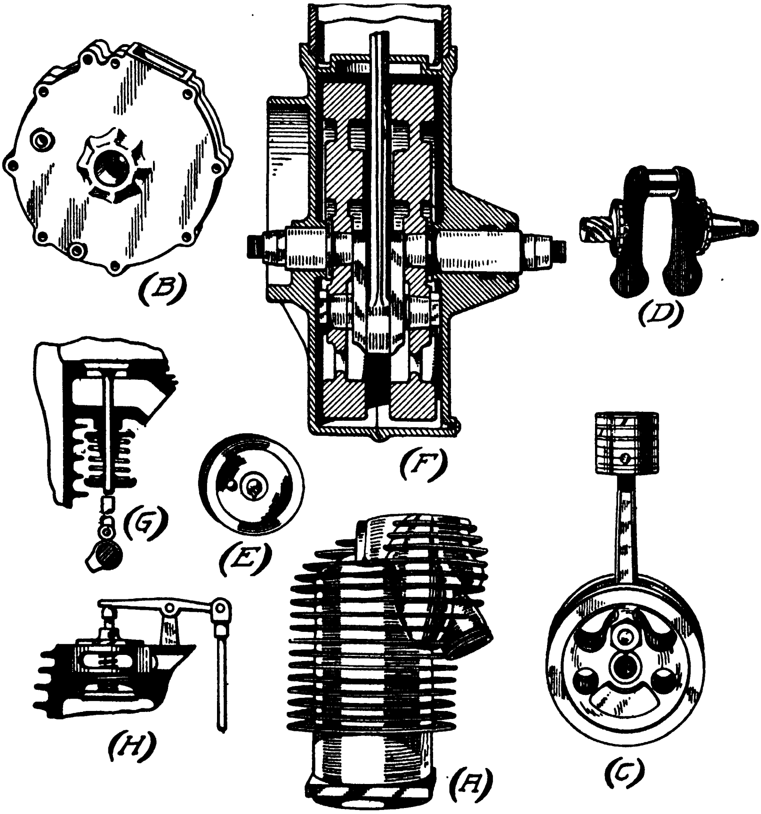


Fig. 1. Diagrams of Various Parts of Motorcycle

A valve assembly is shown at *G*, giving the valve, the valve seat, the valve spring, the tappet, and the cam. The valve usually has a bevel seat as shown, but in some cases it is flat. As the cam is revolved by the gearing from the crankshaft, the high portion comes under the bottom of the tappet and raises it upward. The tappet in turn raises the valve from its seat, allowing gases to enter or to be exhausted from the cylinder, as the case may be. There is often an arm or cam follower *H* interposed between the cam and the lower end of the tappet, but the general action is the same.

It is quite common to use an overhead valve for the inlet, and in that case the valve often works in a removable cage *H* instead of seating directly on the cylinder casting. In order to get the action of the cam carried to the valve, the tappet raises a long push rod and this in turn raises one end of a rocker arm, the combination of motions opening the valve.

OPERATION OF MOTORCYCLE ENGINE

Types. Motorcycle engines of all designs are of the internal-combustion engine type, which means that fuel is burned or exploded inside the cylinder of the engine where the heat energy liberated is transformed into mechanical energy. An example of an external-combustion engine is the ordinary steam engine where the burning of the fuel takes place outside of the engine itself.

There are two general types of the internal-combustion engine, known as the four-cycle and the two-cycle engines. Engines for motorcycle use are usually of the four-cycle air-cooled variety. These engines are now built with one, two, and four cylinders. Fig. 2 shows the Harley-Davidson power plant, which is of the L-head cylinder construction with the inlet valve above the exhaust and operated mechanically by a push rod and rocker arm. Other engines of the V-type have the inlet and the exhaust valves side by side in the bottom of the combustion chamber, while the third school of design places both the inlet and the exhaust valves in the top of the cylinder head, operating them through rocker arms. The four-cylinder four-cycle engine is fast gaining in popularity for motorcycle use and very desirable results are being obtained from this engine for the reason that the vibration is greatly decreased.

Instead of an external single flywheel, the V-cylinder engines have enclosed flywheels with the crank pin and two crankshafts fitted into them by stout tapers. The counterbalances for the inertia forces of the piston are cast as part of the flywheels. With the single crank pin and the two rods there are two possible constructions for the lower-end bearings. One would be with the rods placed side

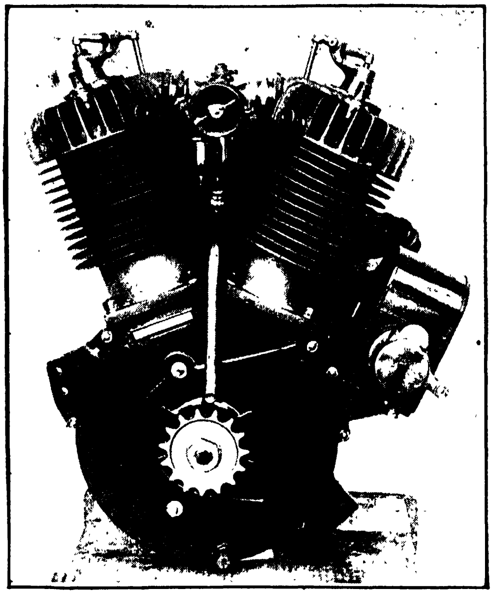


Fig. 2. Side View of Harley-Davidson Twin-Cylinder Engine

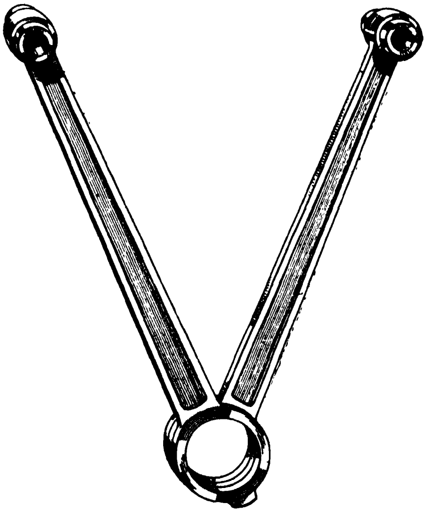


Fig. 3. Typical Forked Piston Rods for V-Type Twin-Cylinder Engine

by side, while the other would be the forked rod as shown in Fig. 3. This is the design that has become standard practice.

In the highest development of these machines, roller bearings are used at the big end of the connecting rods instead of the split bushing. Great skill is required in fitting these bearings, for if one roller is larger than the other rollers by a very small fraction of an inch, there will be a binding of the bearing upon the shaft. When they are correctly fitted, however, and properly lubricated, their life is very long and the friction loss is held at a minimum.

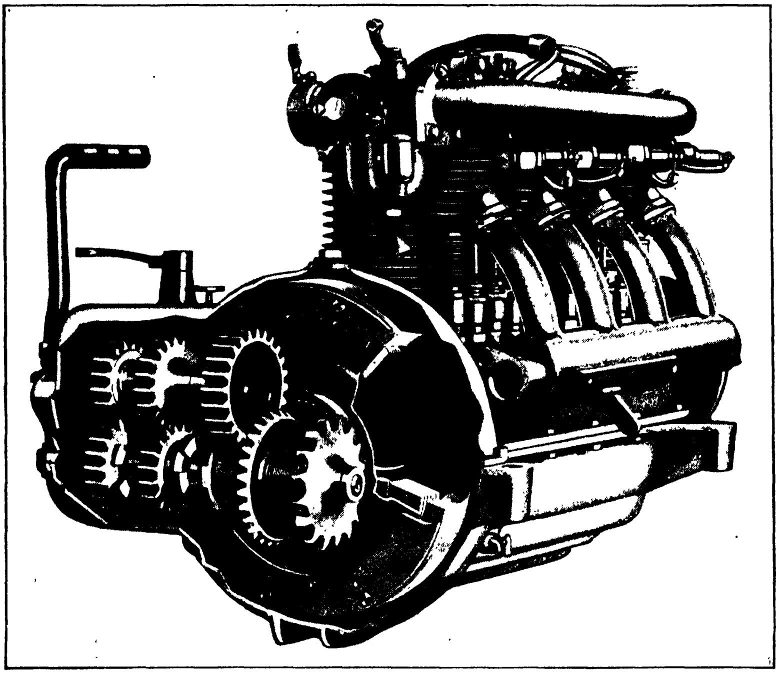


Fig. 4. Rear View of Henderson Four-Cylinder Engine and Transmission
Courtesy of Henderson Motorcycle Company, Detroit, Michigan

Instead of the cams working directly upon the ends of tappets to raise the valves, it is usual to interpose arms or followers as shown in Fig. 2. Just above the cam wheel or the large gear is a small rack or portion of a gear. This is connected to the compression relief and when it is desired to relieve the compression of the motor, this part gear is rotated and, through a lever connected to it, raises both inlet valves slightly off their seats so that the compression is materially decreased.

Figs. 4 and 5 illustrate the Henderson four-cylinder motorcycle engine, air-cooled and of the L-head type, with overhead inlet valves. It is designed for medium-high speed, has a three-bearing four-throw crankshaft, three-ring pistons, an enclosed flywheel, and a bevel-gear reduction. The motor is lubricated by splash from the oil in the base of the crank case, as will be noted in Fig. 5. This engine is particularly neat, noiseless, and flexible.

Lubrication. A lubricating system as used on the Excelsior motorcycle engine is shown in Fig. 6, and gives the particularly neat method by which engines of this type are oiled. In this case, the oil is first fed to the main bearing on the cam-case side, as shown by the arrow. This oil is fed by pressure from a pump and, after covering this bearing, is forced out at the end and flows through the drill hole shown, which brings it out above by centrifugal force to the connecting-rod bearing. This bearing throws the excess oil out, splashing it in all directions and up through the slot through which the connecting rod runs. From here it runs out on either side and gathers in a groove at the bottom edge of the cylinder. The bottom of the piston drops into this trough of oil every time it comes down, thus carrying the even film with it up the walls of the cylinder. The excess oil flows down the side of the crank case and feeds the right-hand bearing. Excess oil from here is caught on the outer end of

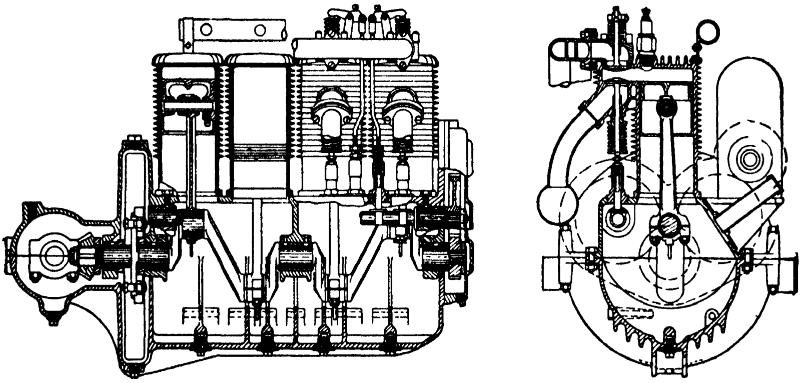


Fig. 5. Side and End Sections of Henderson Four-Cylinder Engine

the shaft and returned to the crank case, where it is splashed up again into the engine for further use.

In a V-type twin-cylinder engine where the oil trough at the bottom of the cylinder cannot catch an even amount on account of the cylinder angularity, the oil is generally allowed to drain back at once on the rear cylinder and, instead of going to a main bearing first, it is fed to the forward cylinder.

Fig. 7 shows a type of oil pump which is used to feed the oil to the engine. In this construction a small worm drive from the cam case or the magneto gear case turns a small crank which operates a vertical plunger. This plunger cylinder is so arranged that on the top of the stroke oil may flow into the cylinder space, a ball check valve holding the oil from being sucked into the cylinder. On the down stroke, the oil inlet is covered by the piston, and the ball check valve opens to allow the plunger to force the oil in the cylinder out of the engine.

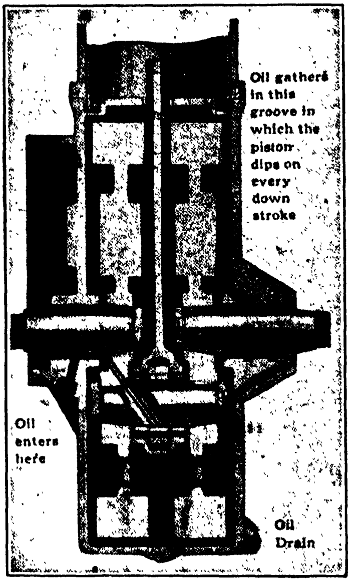

Oil gathers in this groove in which the piston dips on every down stroke
Oil enters here
Oil Drain

Fig. 6. Excelsior Lubricating System

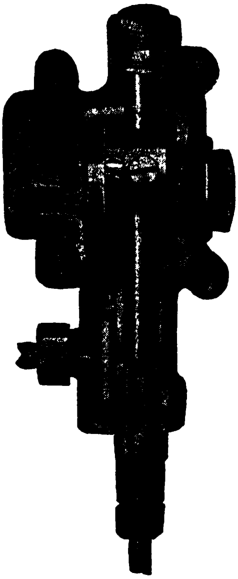


Fig. 7. Excelsior Oil Pump

Fig. 8 illustrates a special type of pump in which the plunger *P* is operated by a peculiar-shaped roller cam *H*. The shaft of this roller cam contains the elements of a rotary valve, with openings at *A* and *D*, so that the oil is fed positively through a sight feed *G* on its way to the engine. There are no ball check valves in this construction, and a screw *J* enables one to adjust the amount of oil delivered to the engine within very narrow limits. The intake oil pipe is shown at *S*. The oil is fed to the engine through the opening *G*. Since oiling is so important a part of the high-speed engine operation, the development of this device has made a change in the reliability of the modern motorcycle.

The quality of the oil used is of great importance in the life of a motorcycle. Each maker recommends oils suited to his machine, and it is well to follow these suggestions.

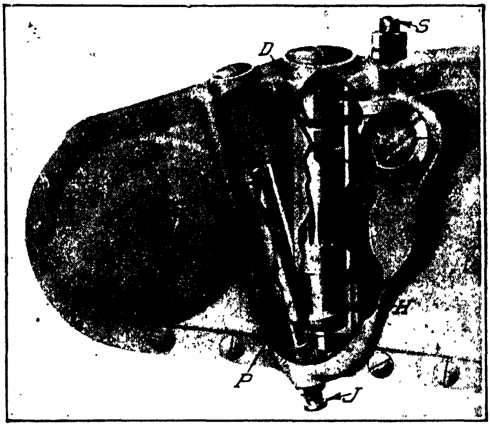


Fig. 8. Harley-Davidson Roller-Cam Oil Pump

Starting. It is hardly probable that the complication of electric starting will be adopted widely for motorcycle use, as it is generally more trouble to operate a power starter and keep it in repair than to use the simple form of kick starter which has become so popular and which now is fitted to almost all American machines.

Figs. 9 and 10 show forms of starters in use on the Excelsior and Indian motorcycles, respectively. The main shaft on one side or the other is fitted with a small gear pinion which is fastened to the shaft on a ratchet or over-running clutch. Off to one side is pivoted a gear quadrant fastened to a pedal, which is often of the folding type. Pushing down on this pedal with the foot meshes the pinion with the quadrant, and a quick thrust or kick of a quarter-turn will then turn the engine over several times at fair speed. When the engine starts, the small pinion is released, and a strong spring brings the quadrant back to its former position, out of mesh with its pinion. The pedal is generally fastened in this upward position by means of a clip so that it cannot rattle.

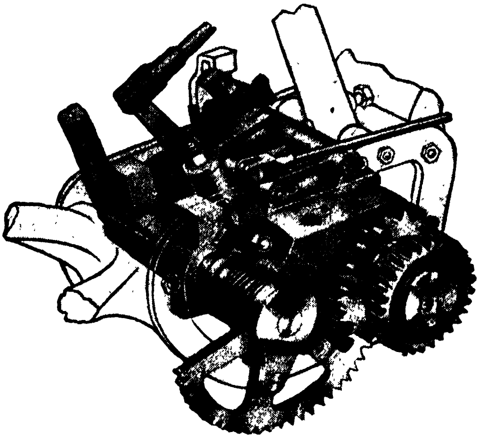


Fig. 9. Excelsior Starter with Automatic Compression Relief

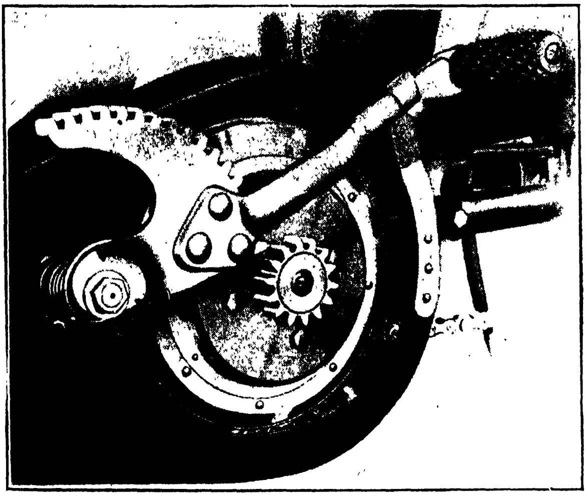


Fig. 10. Indian Kick Starter
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

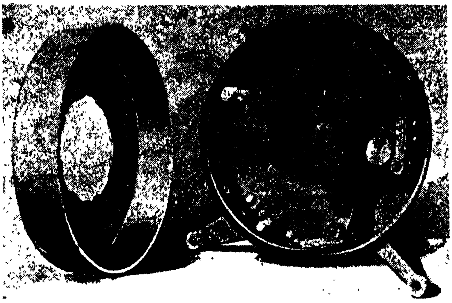


Fig. 11. Typical Expanding-Band Brake
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

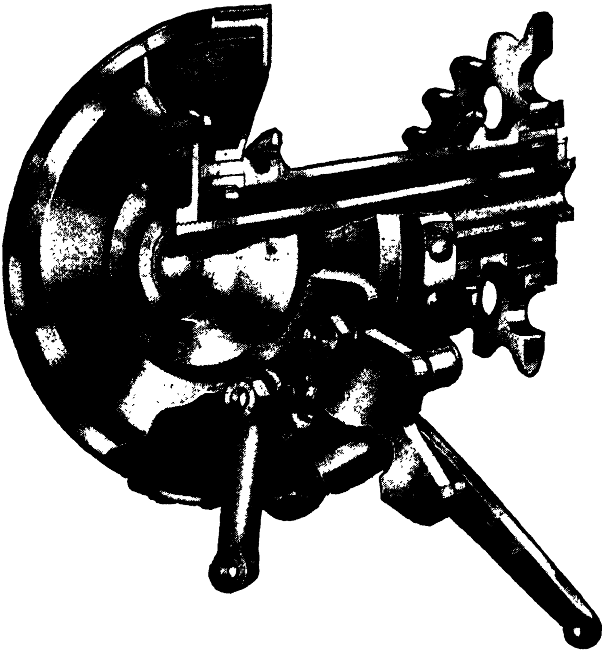


Fig. 12. Typical Double-Acting Band Brake
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois

Brakes. A number of types of brake construction are used on motorcycles, but they are mostly of the expanding- or contracting-band variety. Fig. 11 shows the construction of an expanding-band brake. The band is of springy material and covered with a brake-lining material. The shoe or ring fits inside the brake drum, which is keyed to the rear-wheel hub. Operation of the lever pushes the ends of the band apart so that it expands forcibly against the interior of the drum.

A similar band may be fitted outside the drum, but in this case the fabric will be on the inside of the band, and the lever will pull the band tight on the outside of the drum. This is known as the contracting-band brake. Fig. 12 shows the brake used on the Excelsior motorcycle combining both types, the expanding and contracting bands being shown in section with their linings in place. The operation is by two levers, shown in the lower part of the illustration. Fig. 13 illustrates the pedals fitted to the Henderson motorcycle, which operate the brakes of this complete little machine.

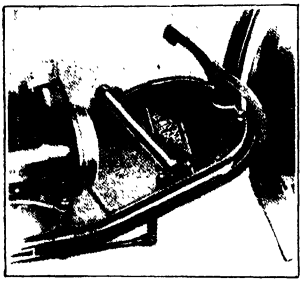


Fig. 13. Henderson Foot Rest and Brake Pedals

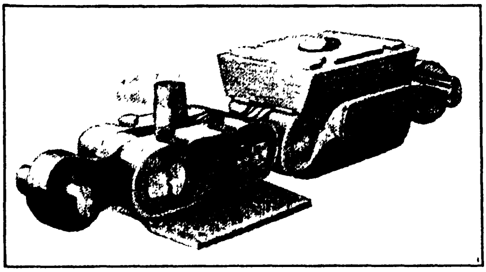


Fig. 14. Peerless V-Belt for Motorcycle Drive
Courtesy of Peerless V-Belt Company, Cedar Rapids, Iowa

Drive. The early motorcycles employed belt drives of either the V- or the flat-faced types. As the power output increased, the belt slippage became excessive and the chain drive began to predominate. In the new light-weight machines, however, the belt drive has reappeared, especially in the V-type of construction, which consists of a continuous two- or three-ply belt of leather with blocks of leather riveted to it, Fig. 14. The blocks are about 1 inch thick, and the sides are beveled off at the same angle as the V-pulleys.

For heavy powers the roller chain seems to have proved itself the most efficient. This construction is the outgrowth of bicycle practice; and we now usually find two chains, one from the engine to the gear set and the other from the gear set back to the rear hub. The chain is made up of a series of rollers turning on hardened pins which stand between the side bars. If kept in proper condition, the friction loss is very small.

Clutches. Several kinds of clutches are used on motorcycles, the one most used being of the multiple dry-disc type, as shown at the left end of Fig. 15. This consists of a number of thin metallic discs faced with fabric brake-lining material and keyed alternately to the center shaft and the containing drum. When springs are allowed to thrust these plates tightly together, the amount of friction generated makes a reliable drive between the drum and the central shaft. Suitable mechanism is arranged so that, when it is desired to disengage the clutch, a lever or pedal can release this spring pressure and allow the discs to run free without friction between them.

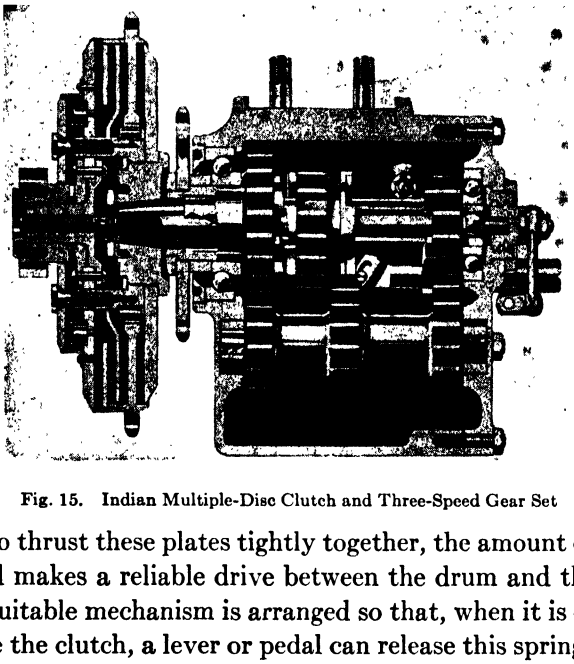


Fig. 15. Indian Multiple-Disc Clutch and Three-Speed Gear Set

Metal-to-metal clutches consist of a set of metal discs brought into or out of contact by means of a lever. These are generally run in oil to prevent their heating. When the spring pressure is applied, it takes a number of revolutions to drive out the oil from between the plates and thus prevent a grabbing clutch.

Gear Sets or Change-Speed Mechanisms. Modern motorcycles are almost invariably fitted with change-speed gears, which might be classed as one-, two-, and three-speed types. The one-speed gear—if it can be so called—is merely a dog-clutch arrangement, Fig. 16, used to disconnect the engine from the rear wheels when the clutch is in engagement. The central part is a ring which can be moved from right to left in order to fit the notches in its face into those on an adjacent ring connected to the driving sprocket. The sliding of this member is accomplished by means of the small lever.

Fig. 17 shows a three-speed gear fitted to the Harley-Davidson. At the extreme left is shown the clutch and the large and small sprockets. The lower shaft to the gear set is the main shaft, and the two gears at the right on this lower shaft slide on keys on the shaft. The shaft is driven by a big sprocket, while the smaller sprocket is fastened to the left-hand gear. If the two sliding gears are shifted to the left, a dog engages them with the left-hand gear, these dogs being clearly seen in the illustration. If the gears move to the position shown in the illustration, the machine is on second speed, driving through the four gears which are in mesh. If the two gears are shifted farther to the right, the right-hand one of the two lower gears comes in mesh with the right-hand big gear, and the machine is on its lowest gear ratio. The method of mounting this gear set on the Harley-Davidson is shown in Fig. 18.

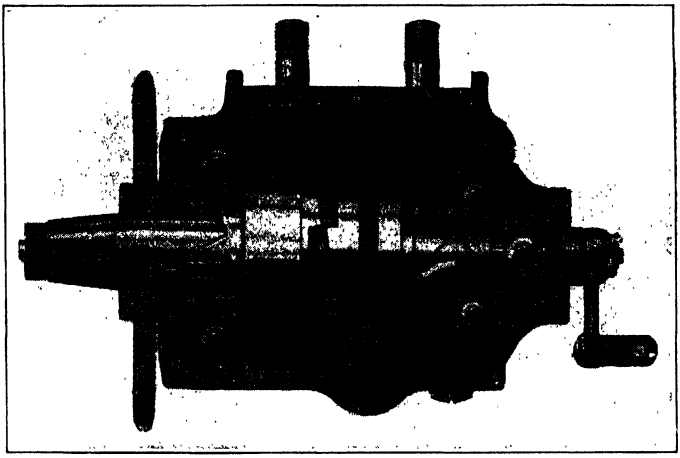


Fig. 16. Indian Neutral Countershaft
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

A smaller three-speed gear set used on the Indian motorcycle is shown in Fig. 15 in connection with the disc clutch attached. In this case a single sliding gear on the principal shaft makes all the connections and gives a progressive gear set of extreme simplicity. A gear set is a necessity on motorcycles intended for passenger use.

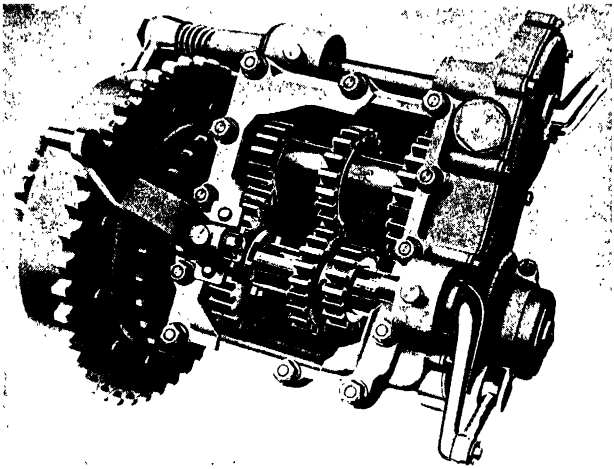


Fig. 17. Harley-Davidson Three-Speed Transmission

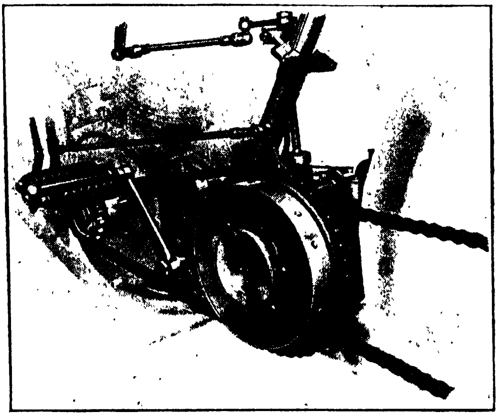


Fig. 18. Method of Mounting Transmission in Harley-Davidson Frame

Electrical Equipment. In the earlier days of the motorcycle, the electrical current for ignition was furnished by dry cells and stepped-up to the required voltage by an induction coil. The next development was the almost universal equipment with high-tension magnetos, which generated the spark mechanically and directly furnished high-tension current. With the coming of electric lighting and starting equipment on all automobiles, the motorcycle enthusiast saw the advantage of the electric head and tail lights, to say nothing of a warning signal, and was not slow to demand this upon his own type of machine. The very nature of dry cells works against their continual use for supplying headlight current, and the storage battery has therefore been the only solution of the problem. However, to be carried upon the motorcycle it must be rather small in size and thereby limited in capacity.

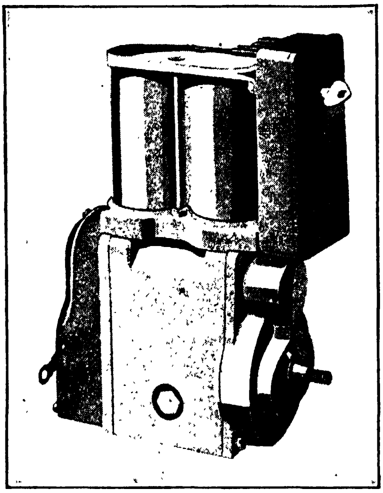


Fig. 19. Remy Motorcycle Generator

In the history of automobile lighting, the owner soon demanded that a generator be driven by the engine for the purpose of keeping the storage battery in a charged condition, instead of having to take it some place for charging from an external source. The same thing followed in the motorcycle field; and we have seen developed a series of generators, Fig. 19, driven mechanically by the engine, which are capable of keeping the battery floating on the line or of sometimes taking care of the lights.

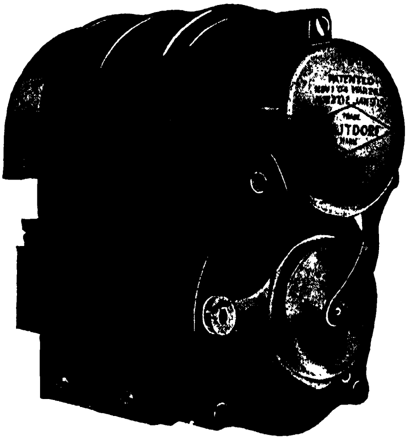


Fig. 20. Splitdorf Magneto-Generator as Used on the Indian Motorcycle

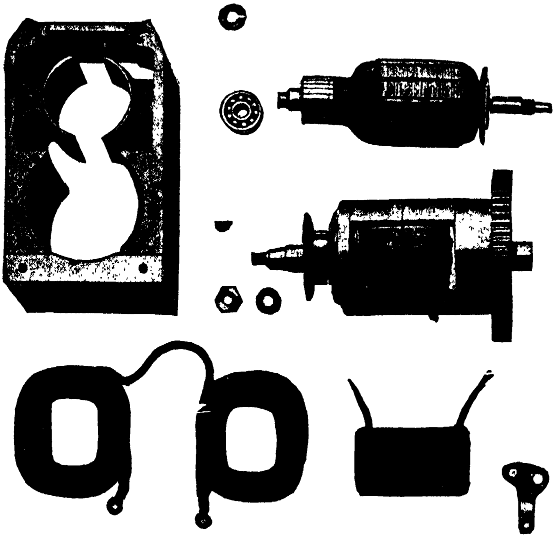


Fig. 21. Parts of Splitdorf Magneto-Generator
Courtesy of Splitdorf Electric Company, Newark, New Jersey

The magneto generators—the Splitdorf type shown in Fig. 20 is used on the Indian—are a unique conception and apparently have not been influenced by automobile practice, for the instruments usually combine a high-tension magneto and a low-tension generator. This combination makes a single-unit machine mechanically, but a double-unit machine electrically, there being two separate armatures, as shown in Fig. 21, the same field winding exciting both fields. In a way, it is wrong to speak of this as partly a magneto, because the term magneto implies the use of permanent magnets for the production of the magnetic field. The armature, however, is of the regular magneto type and delivers a high-tension current to the spark plug. The generator armature is wound so as to deliver about three amperes of current at thirty miles per hour, charging a 6-volt battery. The above description covers, in general, the Splitdorf system.

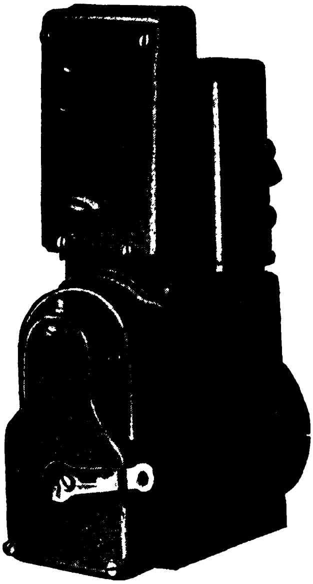


Fig. 22. Midco Magneto-Generator as Used on Excelsior Motorcycle
Courtesy of The Teagle Company, Cleveland, Ohio

In automobile practice it is very common, at present, to use the battery or generator current for the ignition; and in order to do this, a transformer coil is used to step-up the 6-volt current to the extremely high voltage required to jump the spark gaps. This coil is very often mounted right on the generator. The same practice is followed on some of the motorcycle systems, one being the Midco system used upon the Excelsior, Fig. 22. The ignition current is stepped-up by two small coils which are mounted in a protecting case directly above the generator. In a system of this kind there must be both a circuit-breaker and a distributor; these two devices are mounted upon the end of the main drive shaft.

Roughly speaking, the voltage and therefore the current, other things remaining equal, of a generator increases with the speed of the machine. If the generating device is designed to keep the battery in a charged condition at reasonable driving speeds, one can imagine the high charging rate that would result if there were no regulation of the output and the driver "let her out" for several miles over a fine stretch of country concrete. Such a charging rate would probably burn out the winding of the generator itself and also cause serious damage to the battery, owing to overheating and a resulting buckling and falling to pieces of the plates of the battery. One method of regulation is to take advantage of the distortion of the field and attach one end of the field windings to a third brush, as at *A*, Fig. 23. This is known as the third-brush regulation. As the speed increases, the strength of the field automatically decreases, thus counteracting the effect that speed ordinarily has upon the current output. In other cases the regulation is accomplished through the throwing in of resistance into the field circuit, which is done automatically by means of an electromagnetic device.

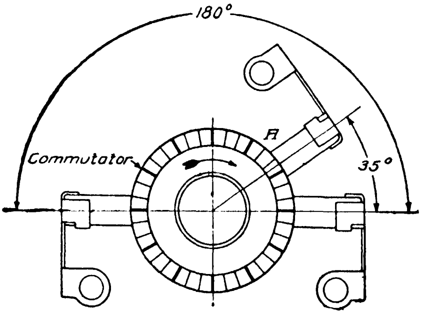


Fig. 23. Midco Third-Brush Regulation

OPERATION OF MOTORCYCLES

Engine. When the engine is in good working order, it requires practically no attention other than to supply it with fuel and keep it properly lubricated. When any serious trouble occurs, a safe plan is to take the machine to an expert and have it properly repaired. This will usually prove the cheapest way in the end. Some of the more common sources of trouble may, however, be located by the use of a little common sense and judgment. It is of fundamental importance that the engine should be securely attached to its base, as otherwise it may be twisted around by the belt or chain and thus thrown out of alignment. It is, therefore, a good plan to go over the engine and its connections from time to time tightening up all loose nuts.

A very common form of trouble is indicated by a knock or pound, which will ordinarily be found to be due either to lost motion or to premature ignition. The pounding due to lost motion indicates too much play between parts which have relative motion and would most commonly be caused by looseness of connecting-rod or crankshaft bearings. Premature ignition, on the other hand, causes pounding of a sharper and more metallic sound and may be due either to overheating or to the fact that the spark is advanced too far. In some cases it also may be caused by carbon deposits in the cylinder, which become incandescent and in this manner cause premature ignition of the gas. A good way to locate a knock is by the sense of sound, which may be assisted by putting one end of a piece of metal, such as a heavy wire, against different parts of the engine and holding the other end between the teeth. The source of the trouble will then be indicated by excessive vibration as the wire approaches it.

The forming of carbon in the cylinder is objectionable, since it causes overheating and loss of power as well as premature ignition. This can be avoided by occasionally injecting into the cylinder a small quantity of kerosene while the engine is warm, turning the engine over a few times, and leaving it thus over night. In the morning the kerosene should be forced out by turning the engine over; the foul oil should be drained from the crank case and replaced with fresh oil.

The leakage of gases from the cylinder, escaping past the pistons because of wear either in the cylinder or in the piston rings, is likely to cause overheating of the upper part of the crank case. When it is found difficult to turn the engine over, the cause is probably the overheating and consequent binding of the piston.

Valves. In order to obtain the best results from the engine, it is important that the valves should be properly seated and that the springs should be neither too stiff nor too weak. It is somewhat commonly supposed that grinding the valves will prove a cure for almost any of the ills to which the gasoline engine is heir. This is a mistake, and valve grinding should not be resorted to unless it is necessary. The grinding of valves is a comparatively simple process, but one that should not be carried to excess as it lowers the valve on its seat; this produces the same effect as does the lengthening of the valve stem, namely, it prevents the valve from seating properly, thereby causing a difficulty greater than that which the grinding was expected to relieve. In order to grind a valve, a paste should be made from emery and oil. This should be put both on the seat and on the edge of the valve itself. Then the valve should be placed in position and turned slowly in its seat by means of a screwdriver, a steady pressure being maintained meanwhile; the turning should, for the most part, be in one direction but an occasional part-turn backward should be taken. During the process, care should be exercised to see that the pressure is in a perfectly vertical direction, as otherwise an uneven grinding will result. In order to tell when this process has been continued long enough and the valve is properly ground the surface of the valve seat and also of the valve may be coated with smoke from a candle; the valve should then be placed carefully in its seat, turned completely around once, and examined. If the grinding has been properly done, a complete bright ring will be seen all the way around.

Carburetor. The proper action of the carburetor is of vital importance to the smooth operation of the engine and on this account when anything goes wrong, it is very common for a beginner to decide at once that the trouble is in the carburetor and begin to tinker with it. As a matter of fact, however, it would be wise for the novice not to attempt any adjustment of the carburetor until he has made a careful study of the type he is using.

Ordinarily, the engine should start without priming the carburetor, unless it has been standing a long time or unless the weather is cold. In case it does not start readily, priming may be resorted to, although it should be remembered that over-priming does more harm than good since the engine then becomes supplied with too rich a mixture, which is as hard to fire as one which is not rich enough. If the gasoline refuses to flow altogether even after priming, the trouble can sometimes be relieved by blowing into the opening of the gasoline tank. Ordinarily, about the only attention the carburetor requires is an occasional cleaning, the frequency of which depends very largely upon the quality of the fuel used and the care with which it is strained. In case the spray nozzle becomes so seriously choked that blowing into the tank will not relieve it, the difficulty can usually be overcome by holding the finger on the priming pin until the carburetor floods, simultaneously racing the engine.

The adjustment of the carburetor can be determined by observing the exhaust. If the mixture is too rich, black smoke and red flame will appear; if it is not rich enough, it will be indicated by a yellow flame; while normal conditions are indicated by a blue flame. An important point to bear in mind is that the proper mixture varies with atmospheric conditions and that a richer mixture is required in cold or damp weather than when it is hot or dry.

Ignition. In connection with the ignition system, it is necessary to be sure that all connections are clean and firmly made and that the insulation is sound throughout. In case of battery ignition it is, of course, necessary to see that the batteries are in good condition. In order to get the best results from the batteries, it is well to have an ammeter with which to test them. New batteries should test from 15 to 18 amperes and about 1.5 volts. When a battery has run down to 4 or 5 amperes, it can no longer be depended upon and should be thrown out. Each cell should be tested separately, and it is never well to connect an old cell with new ones, as the old cell tends to reduce the life of the new ones. The terminals of a battery should never be short-circuited by testing directly across them with a wire or screwdriver, as a battery can be completely exhausted in this way in a short time. It is well to go over all joints and connections periodically, making a careful examination to see that all binding posts and set screws are tight and that all points of electrical contact are bright and clean. The insulation also should be examined from time to time, looking not only for spots where the insulation has been worn away by chafing, but also for any places where it has become saturated with oil. Inspection of this sort is particularly important in the secondary winding, because the insulation in this winding must be much more perfect, on account of the high voltage employed, than in the low-tension primary wiring. In regard to the contact breaker, it is important to see that it is properly adjusted and that the platinum tip is clean and bright.

A common cause of trouble in the ignition system is due to soot on the points of the spark plug. The spark plug should accordingly be removed occasionally and the points cleaned.

The magneto is very seldom the cause of trouble and, under ordinary conditions, should not be tampered with by an inexperienced person. One common source of trouble with the magneto, which can be easily relieved, is the binding of the carbon brush in its holder, thereby preventing proper contact between the brush and the commutator. The same thing will, of course, result if the spring which holds the brush against the commutator becomes weak or is broken.

Lubrication. The matter of lubrication is vital to the satisfactory operation and to the life of a motorcycle. The oiling should not be a perfunctory operation to be taken care of at random but should be done methodically at intervals, depending upon the grade of oil used. Of course, it is possible to go to extremes and oil too frequently, but too much oil is more preferable than too little.

Only the best grade of oils should be used, as the difference in cost is only slight and a poor oil is sure to cause trouble. The manufacturers are always glad to give advice as to the kind and grade of oil best suited to their make of engine, and one would do well to be guided by such advice, since no one knows a machine so well as the maker, and it is also to his interest that the machine gives a good account of itself.

Tires. The principal point to be borne in mind in connection with the tires is that they should be kept pumped up hard, as riding on soft tires is likely to injure both the casing and the inner tube as well as requiring more power to drive the machine. A tire pump should always be carried when on the road, and the condition of the tires should be examined frequently for any indication of softness.

A spare inner tube, sprinkled with tire powder, carefully folded and enclosed in a separate package, should be carried along for replacement in case of a puncture or a blow-out. In addition, a tire-repair outfit for making quick repairs on the road should always form part of the rider's equipment.

In replacing tires with metal tire tools, care should be taken not to chip the enamel off the rim as this will cause it to rust, and the rust will, in turn, injure the tires. On this account, it is well to paint the rims occasionally as a guard against rust. Grease and oil are very injurious to rubber and should never be allowed to remain on the tires but should be washed off at once with gasoline.

Control. The speed and the amount of power developed by a motorcycle depend upon two factors: the quantity of gas supplied to the engine and the time at which the spark occurs with relation to the position of the piston in its travel back and forth in the cylinder. The devices for controlling these two factors or for regulating the throttle and the spark should be conveniently located so that they can be manipulated instantly, while at the same time keeping the hands in position upon the handlebars.

Nearly all the earlier machines were equipped with the twist-grip type of control in which twisting one grip varied the position of the throttle and the other the position of the spark. This type of control has the disadvantage that in heavy going where a firm hold on the handlebars is necessary, the rider is in danger of twisting one or both of the grips unintentionally, thereby varying the position of the throttle or spark at the wrong time. This objection is overcome to a large extent by having the twist grip located in front of secondary grips which are rigidly attached to the handlebars.

Handlebar or lever control is rapidly coming into favor. This form of control consists of levers placed in front of the grips with rod and knuckle joints or with wire cable leading therefrom to the carburetor and to the spark mechanism. Cable seems to be the more satisfactory, for with its use there is no lost motion as is the case with the rod and knuckle-joint system. An advantage of the lever type of control is that the exact position of the levers can be seen at a glance.

Whatever the type of control, the rider should so accustom himself to its manipulation that he can, in case of emergency, throw off the power and apply the brakes instantly. In fact, these operations should be so familiar as to become automatic.

OVERHAULING MOTORCYCLES

Where an overhauling job is on hand, the first thing, of course, is the stripping of all connections between the engine and the frame of the machine. In the repair shop, it is usually handiest to do all the overhauling work on the bench; therefore the whole engine is at once removed from the frame.

Carburetor. Probably the greatest number of calls made upon the motorcycle repair man are for the readjustment of the carburetor. This is often simply a matter of ordinary adjustment, but where the owner finds himself unable to get a satisfactory adjustment, although he has been able to do so in the past, it is usually because of some fault in the carburetor or in its control mechanism. A common source of trouble is the sticking of the auxiliary air valve, which the repair man may often cure by a drop of oil on the shaft.

In the types of carburetors where the amount of opening of the throttle valve controls some other function, as the lift of the needle valve, a great deal of trouble will be experienced by wear and subsequent play of the shaft and connections carrying the throttle valve. The action will be very erratic, depending upon which way the play happens to be when the throttle is being closed or opened; in fact, the engine may even speed up during the closing operation. The repair for this is usually a small bushing to bring the shaft back to firm alignment.

When flooding of the carburetor is not caused by dirt under the float valve, it is usually a matter of a fuel-soaked float. These floats are generally made of cork and the cure is to dry them out and recoat with yellow shellac. When the floats are made of metal, tiny pin holes or porous places in the soldering sometimes develop which allow gasoline to enter, causing flooding. To discover the place of the leak, the float should be submerged in very hot water, which will cause the gasoline to vaporize and bubble through the leaking portion. After this has been marked, a fair size hole should be punched in the top of the float, through which the entrapped gasoline may be drained out. The portion showing the leaks should then be soldered and, after the float has cooled down, the hole in the top should be closed with solder. If this top hole is closed before the leaks are soldered, the heat of soldering will cause a partial vacuum inside the float, resulting in a seepage of gasoline through a seemingly tight float.

Air Leaks in Inlet Manifold. Irregular running may be caused by air leaks at the joints of the inlet manifold. The test for this is to take the priming gun in the gasoline tank and squirt a good quantity of fuel around all the joints. If these joints leak, the engine will die from an over-rich mixture. The same galloping effect that was noted from the poorly seating exhaust valve also may be caused by weak exhaust-valve springs.

When an engine is cold, a certain amount of clearance must be left between the top of the tappet and the valve stem. This is in order that the valve may expand upon heating up and still not ride upon the tappet, which would cause a poor seating of the valve. So far as wear upon the cam and upon the valve mechanism is concerned, it is fortunate that the motorcycle rider is not the fiend for silence that his cousin, the automobilist, has become. For this reason, the valves are set with plenty of clearance, .008 inch being good practice. In some cases the design is such that the cylinder actually lengthens more than the valve, owing to the heat of running. In such a case the tappet clearance would be increased instead of decreased upon warming up, and the noise would probably be excessive. Such engines, of course, may be adjusted much closer than the figure just given. Both the owner and the repair man should have a set of feelers and also two wrenches of the size of the tappet nuts, Fig. 24, so they need not be forced to use a bicycle wrench for making these adjustments. With air-cooled engines, it is surprising how often the tappet clearances have to be checked up for good results.

Valves. A great many times the carburetor and carburetor adjustment will be blamed by the owner when the trouble is from some other source. For instance, the back-firing, which is the usual indication of a lean mixture, may be caused by poorly seating inlet valves. On the other hand, the galloping of the engine, which is usually the symptom of too rich a mixture, may be due to leaking or sticking exhaust valves. On the modern machines one of the

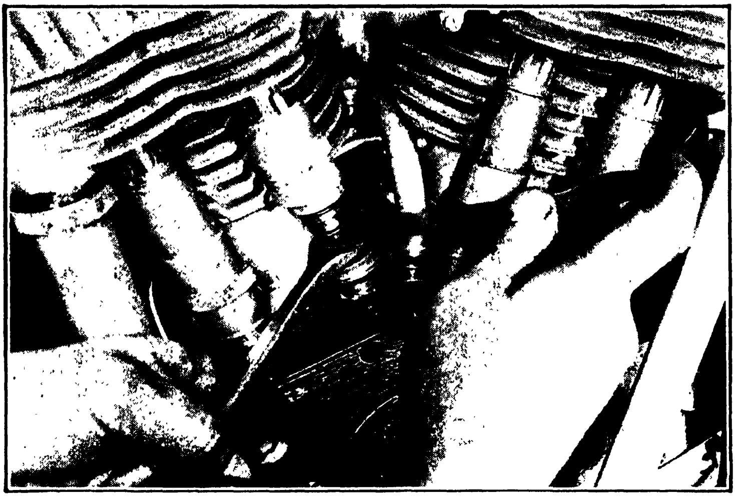


Fig. 24. Handling Tappet Nuts with Two Wrenches
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

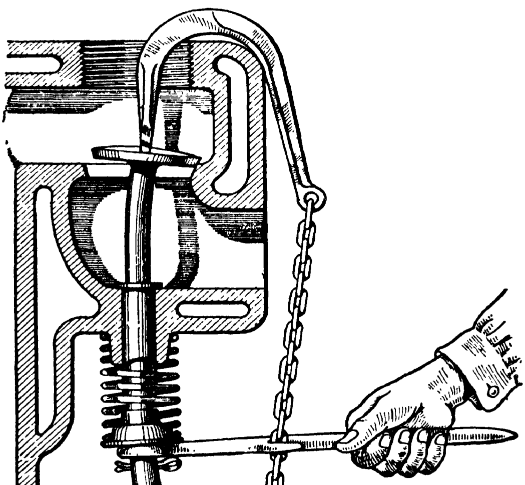


Fig. 25. Diagram Showing Bad Results from Using Valve Lifter with Too Great Pressure

causes for faulty valve spring and valve action is very often the accumulation of dirt inside the sleeves which cover the valve mechanism. The cure, of course, in this case is a thorough cleaning. The cure for leaking valves is a matter of grinding in.

In the removal of valves, the use of valve lifters has become very common, and their operation is so simple that little need be said concerning them. However, there is one warning which is worth while, particularly when using a type of lifter with which the operator is not familiar, and that is to be sure he does not catch the spring retaining-pin in the lower part of the lifter at the same time that pressure is being exerted upon the top of the valve, Fig. 25. The result in such a case would be a bent valve stem, which is very hard to remove.

The scraping of carbon and the grinding of valves go, as a matter of course, with every overhauling job; and, where the majority of the work is with one make of machine, considerable time may be saved in grinding in the valves by having a dummy valve seat. It has been found, particularly in the case of badly-pitted exhaust valves, that it takes a much longer time to obtain a satisfactory surface on the valve itself than it takes on the cylinder seat and, therefore, this dummy will save the unnecessary cutting down of the engine casting. The dummy may be made of cast iron, from a special pattern, or it may be a portion of an old damaged cylinder. Another thing used by one of the large motor-car companies, and justifiable only where a great many machines of the same make are worked upon, is to have made up a special seating reamer that will give a convex surface rather than a flat conical one to the seat in the cylinder. The advantage claimed for this is that it takes less grinding to obtain a gas-tight joint and that the pounding action of the valve tends constantly to widen the seat. Some valves are designed with a flat instead of conical seat, but the grinding process is the same.

Valve Timing. In a complete overhauling job, it is more than likely that the timing gears have been removed for cleaning and inspection, in which case the engine has to be re-timed upon assembling. It is usual for the manufacturer to place marks, in the form of little cuts or prick-punch centers, on the gears, Fig. 26, so that they may be replaced in the proper manner. One method is to prick-punch each set of teeth while under some certain conditions, such as at the point of closing of the exhaust valve. Another method is to line up certain marked teeth with marks made in the back wall of the gear case. It sometimes happens that the manufacturer's marks are not found, and a new set of marks is put on by the repair man before disassembling the job. At a later date, both sets of marks may show up, with a resulting confusion. It is well, then, to know something of the valve timing, instead of having to depend blindly upon the marking of the gears.

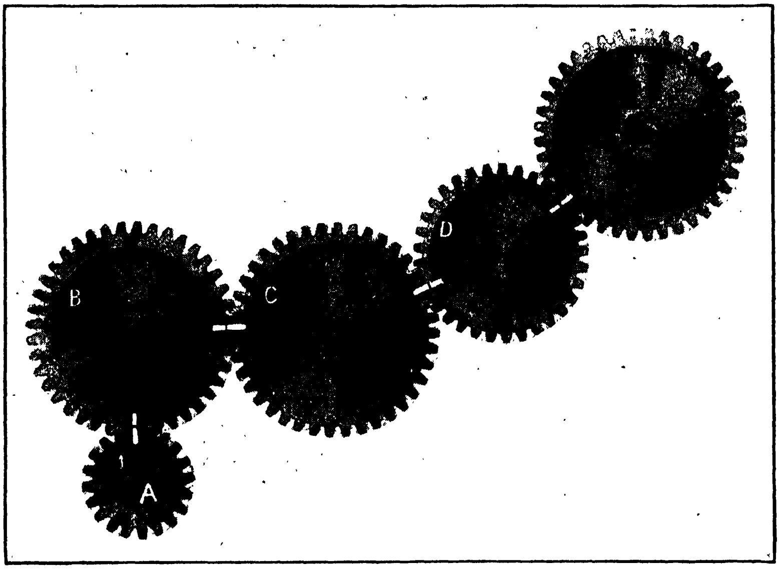


Fig. 26. Method of Marking Timing Gears
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

In the discussion of the principle of operation of a four-cycle engine, one would be led to believe that the inlet valve opened exactly on upper dead center and closed on lower dead center, while the exhaust valve had an opposite performance. This is theoretically true; but practice has shown that, owing to the inertia of the flow of gases and other little-known conditions within the engine, the valve timing can be changed considerably from the dead center points, giving marked improvement in the power output of the engine.

In automobile practice, it is customary to speak of valve timing in degrees on the crankshaft circle, and the openings and closing of the valves are usually laid off and marked upon the rim of the flywheel. Since in most of the motorcycles the flywheels are enclosed, this method is not employed, and where the maker furnishes information as to the valve timing, it is in terms of the travel of the piston from the upper or from the lower dead center, as measured in inches.

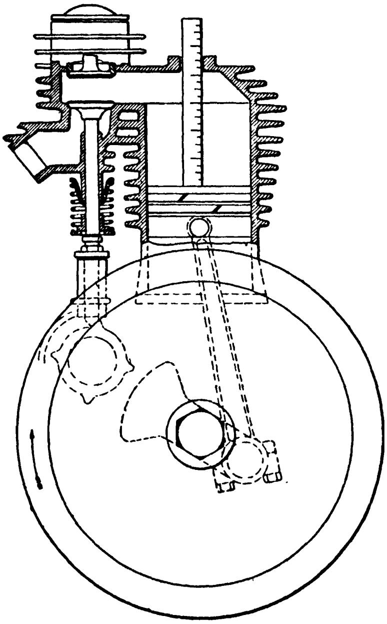


Fig. 27. Method of Following Out Valve Timing by Means of Scale

Where the cams are all made integral, only one point of the timing can be controlled, the other points being in a fixed relation, the accuracy of which depends upon the workmanship in the cam-grinding department. Since the closing of the exhaust and the opening of the inlet is important for smooth running, this is the point that is taken for setting the valves. Fig. 27 shows a very easy method of following out the valve timing. A scale is dropped through one of the openings in the top of the cylinder, possibly the spark-plug hole, and after the dead-center points have been noted, the crankshaft is revolved until the scale shows that the piston has moved down or up the desired distance from dead center. With the crank at this point, the gears are slipped into mesh so that the valve will be just opening or closing, as the case may be.

In some cases, the inlet and exhaust valves can be timed separately. Owing to the inaccuracies in grinding, one seldom can obtain both the opening and the closing points stated by the manufacturer. It is best, therefore, to set the timing on the closing of the exhaust and the opening of the inlet, letting the opening and the closing, respectively, take care of themselves.

The following timing instructions are taken from the instruction book of a well-known maker and are illustrative of the form:

Twin-Cylinder Engine

The exhaust valve should open when the piston is $\frac{5}{8}$ inch to $\frac{3}{4}$ inch before bottom center and should close $\frac{1}{32}$ inch to $\frac{1}{16}$ inch after top center. The inlet valve should open $\frac{1}{16}$ inch to $\frac{3}{32}$ inch before top center and close $\frac{1}{8}$ inch to $\frac{1}{4}$ inch after bottom center. With advanced spark, the motor should fire $\frac{1}{4}$ inch to $\frac{5}{16}$ inch before dead center. Time each cylinder separately as the interrupter housing steel segments are often out of line.

Single-Cylinder Engine

The exhaust valve should open $\frac{5}{8}$ inch to $\frac{3}{4}$ inch before bottom center and close $\frac{1}{32}$ inch to $\frac{3}{32}$ inch after top center. The inlet valve should open on dead center and close $\frac{1}{4}$ inch to $\frac{3}{8}$ inch after bottom center. The spark timing is the same as that of the twin.

Piston Pins. Whenever the engine is down, the repair man should not fail to look at the fastening of the piston pin to see whether there is any trouble in that direction. A piston pin which comes loose and works sideways will act exactly like the tool in a shaper, cutting a broad groove down the side of the cylinder. As a general rule, the piston-pin bearings are bronzed bushings and, although wear at this point is not commonly excessive, poor lubrication or very great mileage will produce play. This causes a knock which is very often mistaken for a piston slap. The remedy, of course, is a new bushing or, very possibly, both a bushing and a pin.

Big-End Rod Bearings. At the lower end of the rod, the big-end bearings in the large twin machines are usually of the roller type and when these give trouble, new sets of rollers have to be fitted. In case it is simply a matter of wear from long service, slightly oversized rollers are used. This particular job is one requiring unusual care and skill, and the repair man should be absolutely certain that the rod can be spun on the shaft for any length of time without the rollers climbing or jamming owing to the presence of some of slightly different size. In some of the older machines bronze bushings were used for the big-end bearings and these, of course, are much more easily renewed.

Gaskets and Washers. It has been found that it does not pay to try to make use of the old gaskets in putting the job back together, as they are almost sure to leak. New felt washers at the crank case should also be used, even though the old ones seem in pretty fair shape, for before another overhauling it is more than likely that the old ones will begin to leak oil.

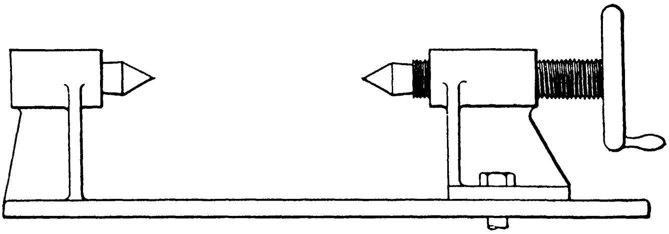


Fig. 28. Set of Centers Made Up for Handling Crankshafts

Truing-Up Crankshafts. When the built-up type of crankshaft and the double flywheel have been torn down for the fitting of new bearings or for some other purpose, they are quite sure to be out of true when reassembled. In some cases, a line is marked upon the surface of both flywheels, and the truing is done by placing the crankshaft ends on blocks and striking with a soft hammer until a steel straightedge may be laid across the flywheels so as to exactly coincide with the two lines and show no light underneath on the flywheel surfaces. An even better way of truing the assembly is to have made up a set of centers, similar to Fig. 28, and by the use of a machinist's gauge discover where the crankshaft is out of true. It is then straightened by the hammer method. In the first case, it is really the flywheels that are being trued, while in the second case, it is the more important shaft itself. Before the truing operation, the nuts may be drawn up good and snug; but after the truing is done, it is found that they can be drawn still tighter.

Oily Clutches. The dry clutches with alternate discs covered with a woven fabric of asbestos and brass or with copper wire give considerable trouble from slipping, owing to the presence of grease or to the glazing of the surfaces. When grease is the cause, the clutch is disassembled and washed in gasoline. One shop takes the plates and piles them in pairs and then sets fire to pieces of oil-soaked waste, shown in Fig. 29, in order to completely burn out all the grease. The surface is then roughened up with coarse emery cloth and chalked, after which the clutch is again assembled. The chalk is for the purpose of soaking up the grease and of giving a fairly harsh engagement. In case the trick has been overdone, a little engine lubricating oil squirted into the clutch will make the engagement easy again.

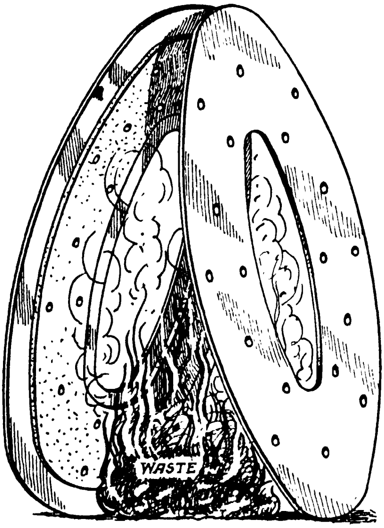


Fig. 29. Burning Oil Off Clutch Discs

The most clutch trouble has come when a side car has been added; and in one case the makers provided for this by so designing the clutch that the usual equipment of eight springs could be increased by eight when a sidecar or a delivery van was attached to the machine. This makes the clutch action suitable under all kinds of service. Most motorcycle clutches, whether of the cone or of the disc type, have more than one clutch spring—usually three or five. It is of very great importance, therefore, in adjusting one of these clutches, to give the nuts on each spring exactly the same number of turns, otherwise the action will be very unsatisfactory and the clutch liable to serious damage. On some of the older cars with belt drive, the clutch has been accused of slipping when, in truth, the trouble was with the belt. This resulted in continued adjustment of the clutch, until the load upon the thrust bearing was so great that it went to pieces.

Cleaning Chains. A roller chain and set of sprockets is a highly efficient transmission unit when kept in good condition, but not otherwise. One or more times during a season, depending upon the mileage, the chains should be removed, cleaned well in gasoline or kerosene, and then let soak over night in oil. The next day, they should be hung up to drip until they are dry. There is no use trying to hurry the oiling process, as the object is to let the lubricant work into the small bearings between each pin and roller.

Although chains and sprockets are laid out by the designers, with such a number of teeth that the one particular link of the chain will be a long time reaching a particular tooth for a second time, it does sometimes happen that the wear is not evenly distributed. In such a case, a chain which was satisfactorily quiet and apparently having considerable service left in it will be found noisy or will bind when replaced after the overhauling. Before their removal, therefore, it is not unwise to mark in some way the position of the chains and to return them to the same location after the cleaning process.

Dirty Muffler. There is one unit of the machine which the careless repair man or the amateur may neglect to go over in the overhauling job, and that is the muffler. This is a grave mistake, for an air-cooled engine naturally burns a good deal of cylinder oil; and it will be found that after a season's running the muffler will be pretty well choked up with carbon. With an engine which has been burning an excessive amount of oil there may even be an accumulation of carbon and oil in the muffler, which will be of the consistency of wet cement. These conditions produce a back pressure upon the engine, which cuts down the power no matter in what mechanical condition the engine may be. If the muffler is clean and clear, there is really no excuse for the cut-out except in testing for engine operation.

CORNER OF MACHINE SHOP IN OHIO-BUICK COMPANY'S SERVICE CORPORATION

SHOP INFORMATION

PART I

Importance of Shop Equipment. The average garage or repair shop should be equipped to do any repair job which comes into the shop. Of course, the demands in different districts vary somewhat, but a study of the requirements will guide the management in the installation of the equipment necessary. This article is intended to cover the more common bench operations and the operations performed on the various machines which are most necessary.

BENCH WORK

Bench Position. The work bench should be placed where the best light can be had and where daylight can be used as long as possible. Sunlight should not be allowed to fall directly on the work because, if the metal is bright, the eyes will tire very quickly. When artificial light must be used, the light should be placed slightly ahead of the workman and in such a position that there are no shadows thrown upon the vise or the work.

Work Bench Design. As a large portion of the repair work in a shop is bench work, the height, width, and equipment of the work bench should be carefully considered. The machinist's bench at which hand work is ordinarily performed should be of substantial character, about 2 feet 10 inches from the floor and 2 feet 3 inches wide, Fig. 1. For the sake of economy it is usual to have a $2\frac{1}{2}$- or 3-inch plank at the front to which the vises are fastened and on which all the heavy work is done, while the rear of the bench is made from 1-inch lumber. Maple and birch are preferred as materials for a bench, although ash makes a very good substitute.

When the workman stands on a cement floor, the feet become tired very quickly. A wooden rack, or board, upon which to stand will add to the efficiency of the workman and he will not tire as quickly. A seat to sit on is a great help especially in work that requires considerable filing. In fact, anything that can be done to make the workman comfortable at his bench will help the work output both in quality and quantity.

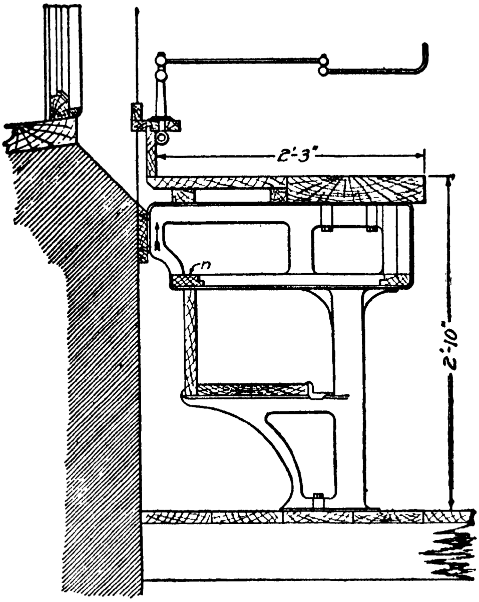


Fig. 1. Work Bench
Courtesy of Brown and Sharpe Manufacturing Company, Providence, Rhode Island

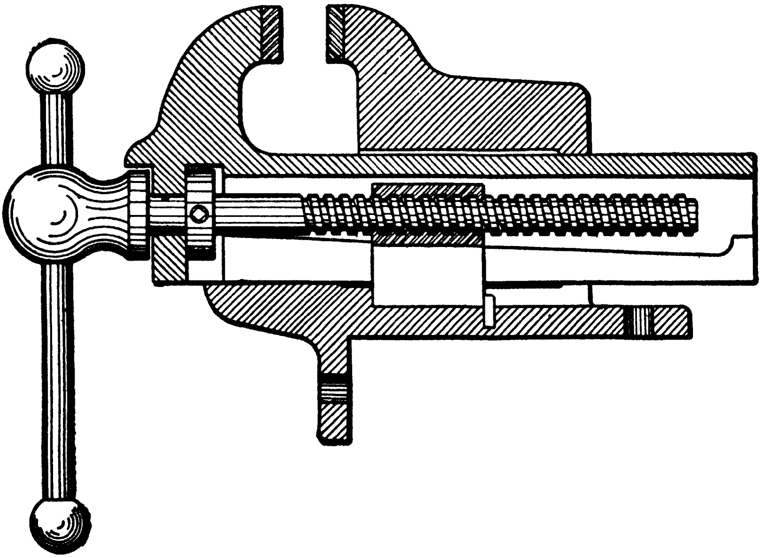


Fig. 2. Simple Bench Vise

Work Vises. In order that work may be held rigidly for the performance of hand operations, the machinist uses what is termed a vise. They are made in a great variety of forms and sizes, but all consist essentially of a fixed jaw, a movable jaw, a screw, a nut fastened to the fixed jaw, and a handle by which the screw is turned in the nut and the movable jaw brought into position. The sectional view, Fig. 2, shows these parts clearly and also a device, present in some form in all vises, by which the movable jaw is separated from the fixed jaw when the screw is backed out of the nut.

In the machinist's vise both jaws are made of cast iron with removable faces of cast steel. These may be checkered to provide a firm grip for heavy work, or may be smooth to avoid marking the surface of the plate operated upon. When holding soft metal, even the smooth steel jaws would mar the surface; and in such cases it is customary to use false jaws of brass or Babbitt metal, or to fasten leather or paper directly to the steel jaws. The screw and handle are made from steel and the nut from malleable iron.

The common method of fastening a vise to the bench is by means of the fixed base shown in Fig. 2, although a swivel base is really preferable. Vises of this kind often have swivel jaws as well, which enable them to hold tapered work securely. This swivel jaw is provided with a locking pin, which fixes the jaws in a parallel position. The height of the vise from the floor depends somewhat on the class of work to be performed, but a general rule is to have the top of the jaw about 1½ inches below the point of the elbow when standing erect beside the vise.

CHIPPING AND FILING

Chisels. One often hears the term "cold chisel mechanic" used in derision, but the man who can by the use of a hammer and hand chisel remove metal neatly and without marring the adjacent parts is a really good mechanic. The term came from the common practice in the early days of the automobile of tightening nuts in place with a cold chisel, which, of course, scarred the nuts very badly. This practice was more the fault of the maker than of the mechanic, as there were places on the automobile where a wrench could not be used. There is now practically no excuse for the use of the cold chisel in this manner.

It is often necessary, however, to remove interfering lugs, etc., when fitting accessories to a car. This is especially true when putting ignition apparatus, lighting and starting equipment, and other attachments on Ford cars. In cutting soft steel with a hand chisel there is little danger of doing damage except by cutting too deep or letting the tool slip, but in cutting cast iron, cast aluminum, and cast brass, which are the metals usually encountered on the motor car, there is great danger of cracking the adjacent part in case deep cuts are attempted with the necessarily heavy hammer blows.

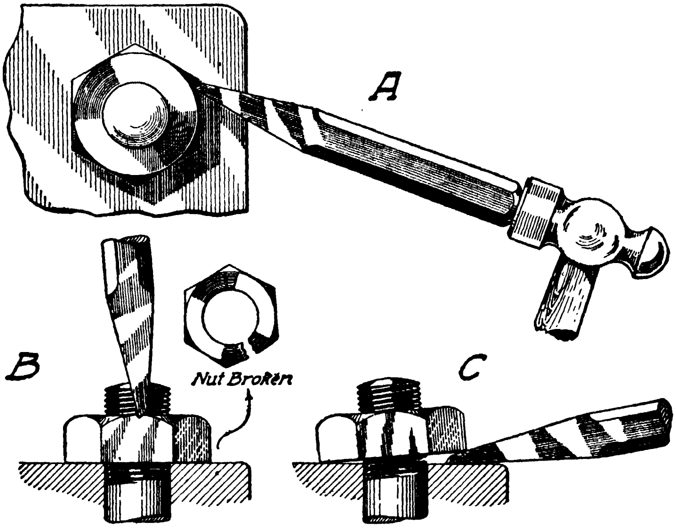


Fig. 3. Methods of Using Chisels on Bolts and Nuts

A survival of the old cold-chisel-mechanic days is found in the method of removing nuts. In these days such practice should seldom be necessary around the engine, but it does sometimes happen that nuts on the muffler and other chassis parts become so badly rusted in place that they cannot be removed by a wrench even after the kerosene-oil treatment. The first thing is to try to start it with a dull chisel at *A*, Fig. 3, but if this does no good and it is desired to save the male member, the nut can be split as shown at *B*. If it is on only an ordinary bolt that can be renewed from stock, it is easier to sheer the bolt, as at *C*, Fig. 3.

Cutting keyways by hand and putting oil grooves in anti-friction metal bearings are the other two uses made of the cold chisel by the automobile mechanic, and these subjects will be taken up in detail later.

Chisel Types. Common forms of hand chisels are shown in Fig. 4 in the following order from left to right: flat, cape, diamond, and two types of round nose.

Flat Chisel. The flat chisel is the most used and works best where the surface to be cut is of less width than the edge of the tool. It is beveled on both sides, an included angle of 70 degrees being best for cast iron, while 60 degrees seems best on wrought iron and steel.

Cape Chisel. The cape chisel is a narrow chisel with the sides ground back so as to give clearance to the cutting edge in a channel. It is used particularly for cutting keyways and for making channels in a large surface preparatory to using a flat chisel.

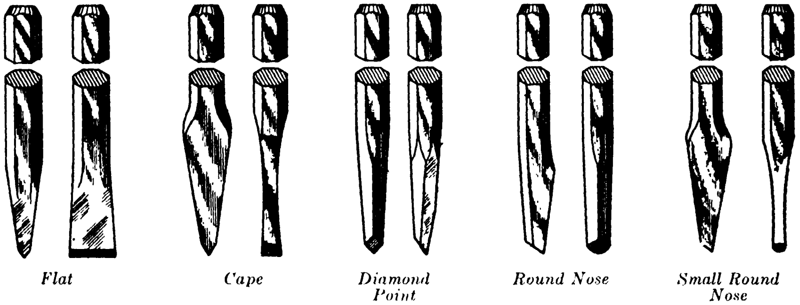


Fig. 4. Common Forms of Hand Chisels

Diamond Point. The name describes this tool, which is used for cutting sharp-bottomed grooves and for putting holes in sheet metal. It has little application in automobile work.

Round Nose. Round-nose chisels, some very small, are of great importance in cutting the oil grooves in babbitt and die-cast bearings. These are often made with curved shanks.

Drawing Out and Hardening Chisels. In a great many repair shops, a blacksmith is not employed. Therefore it often becomes necessary for the mechanic to draw out and retemper his own chisels, screw drivers, and other tools. These tools are usually made of ordinary carbon steel which can be forged and hardened. In some cases, lathe tools are also made of carbon steel but self-hardening steel is in more general use today. The difference between the two steels is that the carbon steel must be heated to a certain heat, chilled, reheated, and chilled again after which it is tempered, while the temper comes in the self-hardening steel as it gradually cools. The object of tempering steel is to enable it to retain its cutting edge. Self-hardening steel can be forged into any shape for lathe tools and its quality of self-hardening enables it to stand up under the heat of friction which will soften the ordinary carbon steel.

The term "drawing out a chisel" means to reforge or reshape the chisel. The chisel is heated to a bright red and then hammered on all sides until it is the shape desired. Care should be taken not to heat the chisel to a white heat. If steel in the chisel is made too hot, the metal is burned and will not be of very much use. After the chisel is formed, it should be allowed to cool and then tempered.

There are two ways of tempering: (1) heating the chisel only once, and (2) heating it twice. In both methods a pail full of clear cold water and a piece of rough emery cloth for polishing the steel after it is chilled should be used. In the first method, heat the chisel to a cherry red. The color of the heat can be easily seen if the chisel is held in a dark place. Dip the chisel in the water in a vertical position for an inch and a half from the point and quickly polish the chilled part with the emery cloth. After polishing, it will be noticed that there are some colors showing at the end of the chisel and among the colors is a dark straw color. The colors will flow toward the point of the chisel and are made to do so by the heat of the unchilled part of the chisel. When the dark straw color reaches to within about one-eighth of an inch of the point of the chisel, it should be plunged quickly into the water, in a vertical position and allowed to cool.

In the second method, heat the chisel to the cherry red color and then plunge it into water until thoroughly cool. It is then dead hard. Polish the chisel with the emery cloth for a distance of about two inches back from the point. The chisel is then heated at the middle with a gas flame or blow-torch. While doing this, the colors, which soon begin to flow, should be watched and when the dark straw color appears, as in the first method, the chisel should be plunged into the water. Do not concentrate the heat in one spot or the chisel will crack when it is suddenly cooled. When it is heated in one spot, this spot is called the water mark and cannot be seen. If the chisel is hit with a hammer, it will break off at this mark leaving a clean break which shows a grey colored cross-section. The flame should be moved backward and forward from the middle to the head of the chisel.

The chisel is then ready for sharpening and use. When grinding the chisel to an edge, be careful not to make the colors flow or the temper will be destroyed. The color at the point of the chisel should not be allowed to become blue before dipping or the chisel will be too soft. Screw drivers should be tempered to a blue color.

In use, the head of the chisel becomes hammered over and very sharp. If this head is not ground off, it is liable to cause injury to the user. Should the chisel slip under a hammer blow or the end of the piece of metal break at the last stroke of the hammer, the chisel may be driven into the hand.

Chipping. The ball-peen hammer seems best balanced for the chipping process, and the size of the hammer should be consistent with the chisel being used and the class of work in hand. Warning has already been given against unnecessarily heavy blows on any part of iron, aluminum, or brass casting, because these metals are very brittle. Only the cutting edge of the chisel should be in contact with the work, the lower bevel being at a slight angle. For a deeper cut the shank is raised, and for a shallow cut the lower bevel should almost touch the work. The general tendency is to raise the chisel too high and thus drive into the piece instead of making a good cut. When chipping material that has a scale, the mechanic should always wear goggles or glasses to protect the eyes from sharp pieces that fly off under the chisel and hammer blows.

FILING METHODS

Types of Files. The greatest time-saver in filing, as a feature of bench working, is in the selection of the correct file for the work at hand. It is therefore imperative, if a shop is to be at all efficient, to have a stock of files which will take care of every kind of work. Although there are a great number of shapes and sizes available with every imaginable type of cutting surface, those most commonly used are the flat file, hand file, warding file, square file, triangular file, half-round file, and the round file.

Files can be obtained which will cut across one angle of the file or one in which the cutting surfaces cross each other. These are known as single or double files. Different materials to be worked on require different coarseness of the cutting surfaces, and there are five general grades most suitable for general work: coarse; bastard; second cut; fine, or smooth; and superfine, or dead cut.

File Shape. In files of fine cutting surface, the length is much shorter than in files with coarse cutting surface. The reason for this is obvious, inasmuch as in heavy cutting one needs a long clean sweep where plenty of muscular effort may be applied to the best advantage; while in fine cutting where the work is more delicate one needs a file which is light and easy to handle.

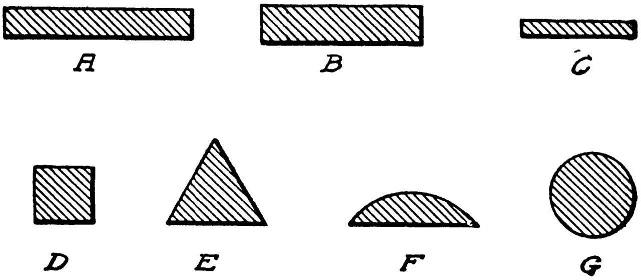


Fig. 5. Sections of Different Types of Files

Properly constructed files have a very slightly convex surface in the direction of their length. The reason for this is that a perfectly flat file surface, digging-in to the full depth of its cutting ability, presents too much cutting surface to be handled by manual power. With a convex surface, however, the file is first applied at the center of the cutting surface, and this bites into the metal, allowing the rest of the file to be carried in easily. This convexity avoids dulling the cutting teeth, for it prevents frequent skimming strokes over the surface of the metal which, as they apply only the sharp edges of the file, quickly breaks them down. This is naturally not the case when the teeth are deep into the metal. Another purpose which this convex surface serves is to compensate for the bending to which a file is naturally subjected when pressure is applied to it.

Although convex in its natural position, the bending action of the file, due to its pressure after the teeth have cut in, very nearly makes up for the convexity. This is, of course, not an accurate compensation.

Proper Files for Certain Work. Before discussing the proper methods of handling files, it will be well to discuss the kind of file to select for a certain work, Fig. 5. This is a matter upon which no fixed rules can apply. One mechanic may do a certain job with a long coarse file, where another may do the same job in equally quick time and as well with a finer cutting surface.

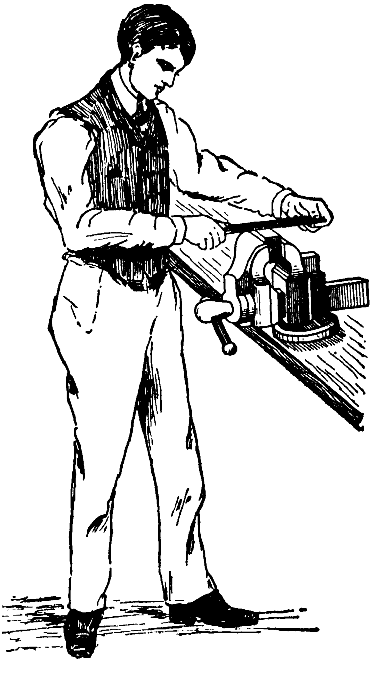


Fig. 6. Correct Bench Filing Position

Generally, however, the kind of metal being worked determines the character of the file to be used. For cast iron, which presents a clean surface free from scale and an undue amount of rust, a bastard file is generally used. Although this is a softer metal than steel, it presents a surface of porous glassy character which is very hard on the cutting surfaces of a file. Old files—ones whose cutting surfaces have already been dulled by long use—should be used in cast-iron work. On steels of all kinds a second-cut file is generally accepted as presenting the best surface. The superiority of the second cut over the bastard for steel work is due to the fact that the cutting surfaces are shorter, and when sufficient pressure is applied for the file to bite into the surface, there is less tendency for these surfaces to chip off than there is with a coarser file such as the bastard.

Aluminum, bronze, brass, bearing metals of all kinds, and kindred soft metals permit the use of flat files with coarse cutting edges.

Manipulation of Files. In filing, the work is usually held rigid in a vise, although many jobs are done directly on the automobile itself. In bench work, the surface should be at about the height of the elbow, and in constructing benches and installing vises it is well to bear this in mind.

Handles. Although it might appear to be a trivial matter, one cannot be too particular as to the kind of a handle which is fitted to the file. Before buying your files, hold them in your hand, with the handle against the palm and the other hand holding the steel end of the file. Press the file vigorously against a surface and determine for yourself whether the handle fits the palm in such a way that several hours of work would not become painful. Also make sure that the axis of the handle is on a true parallel with the file.

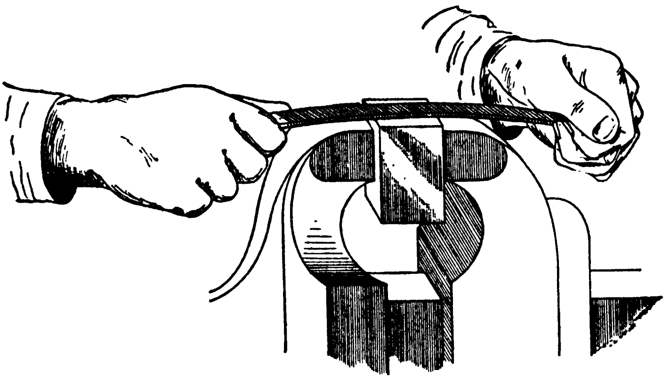


Fig. 7. Position of the Hands for Bench Filing

Position for Filing. If one is to undertake a filing job which will require several hours of concentrated labor, it is well for him to learn that position which will give greatest accuracy and which, at the same time, will be the least tiring. The feet should be placed a foot apart and at right angles to the work bench, or nearly so, Fig. 6, the left foot being in line with the top of the vise and the right slightly ahead of the left. This position allows the body to follow the file accurately and eliminates that swinging sideways movement which is disastrous to accurate work.

Holding the File. Take hold of the handle of the file with the right hand as you would take hold of the steel wheel of the car, with the fingers underneath and the thumb lying along the top. When a big file is used and the work is heavy, grasp the steel end of the file with the left hand by placing the top of the file into the palm and twining the fingers around the end, Fig. 7. If the work is delicate, it is only necessary to pinch the end of the file with the fingers of the left hand.

Remember that the first dozen strokes of a new file on a tough piece of steel frequently lessens its cutting value as much as an hour of steady cutting on a softer metal. Handle the file firmly and push it into the metal with an even steady stroke to avoid chipping the edges. When much metal is to be filed, the direction of stroke should be changed frequently, thus permitting more accurate work as well as allowing faster removing of metal. The file, when moved endwise, produces small grooves in the direction of the work; when the direction of the file is changed, it cuts into the top edges of the grooves with much the same effect as working against the grain in wood.

Uses of Different Shapes of Files. We have gone into the types of files to be used as to coarseness or fineness of the cutting surfaces. Now let us consider the shapes best suited to various kinds of work.

When one selects a file for a certain job, he must bear in mind the shape and the size of the work, the quality of the metal, the amount of stock to be removed, and the quality of the finished work. The first two mentioned requirements fall under the shape of the file, the others under the nature of the cutting surfaces.

If the surface is a flat one, the flat file, hand file, or warding file will serve. The length will, of course, depend on the length of the surface to be filed. For very light work the length of the file should be about 8 inches, and for heavy work about 18 inches. If the surface is a square interior, such as a keyway, the square file finds its place.

The triangular file finds its use in notching round bars, in cutting through steel tubing, and in filing gear teeth, bolt threads, and kindred applications. The half-round file is used where the curvature of a radial filing job becomes too great for efficient work with a round file. With these large surfaces, it is not possible or even desirable to have the file fit accurately the surface to be cut. In using this file it is imperative, if smooth work is to be done, that the file be given a side sweep with each stroke. The round file, which in its general form is tapered throughout its length, has obvious uses in working with round holes.

Accurate Filing. The matter of accurate filing is a knack which can be acquired only by practice. It is the process of learning a smooth even stroke in which the file is held flat against the work throughout the length of the stroke. However, the file maker has contributed towards accurate work in a safe-edge instrument which has innumerable applications around a motor car.

Use of Safe Edges. Suppose one desired to increase the depth of a keyseat without in any way impairing the surfaces on the sides of that keyseat. If he were to introduce a flat file with cutting edges on all four surfaces, he would have removed considerable metal constituting the sides of the keyseat before he had cut the keyseat much deeper. For this kind of work there is the safe-edge file—one in which there are cutting surfaces on two opposing sides and smooth surfaces on the other two. These are procurable in all sizes and shapes.

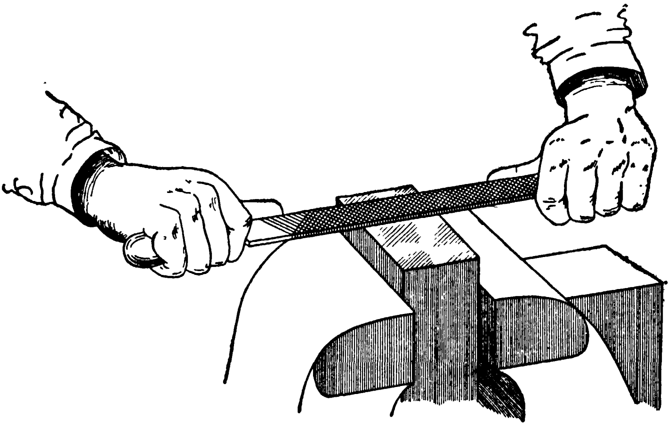


Fig. 8. Position of the Hands for Draw Filing

Draw Filing. The term draw-filing refers to the process of operating the file over the work at right angles to the length of file. To do this work properly, the file is grasped in the palms of both hands, as one would grasp the handles of a push cart, Fig. 8. The purpose of this method of filing is accuracy in the work. As the belly of the file can be brought to bear on the high spots under better control and with less oscillation than in cross-filing, a less skilled mechanic can obtain more accurate results. Of course, due to the fact that the cutting surfaces operate on a great angle, the amount of cut at each draw is far less than it is in cross-filing.

Filing to a Micrometer Fit. Suppose one has a square block of steel, one side of which is to be cut down to an accurate surface with $\frac{1}{16}$ inch of stock taken off Calipers or micrometers should be set about $\frac{1}{64}$ inch greater than the finish size of the block. The surface may now be cut down with a flat second-cut file until the piece will just pass within the calipers or micrometers. Now the micrometer or calipers should be set to the exact dimension of the finished piece, and draw filing should be resorted to so as to cut down the surface carefully until the caliper or micrometer is a very tight fit over all the edges and through the center.

Now one should use a small file of a smooth fine grade for the final dressing off and should resort to the cross-filing method, so as to remove the grooves caused by the draw-filing operation. With a little filing, then a measurement from the caliper or micrometer, a little more filing, and still another measurement, etc., a very accurate job is possible.

Revolving Filing. Quite another angle is presented in revolving filing. This means the filing of a piece of work which is revolving in a lathe chuck. The stroke for this kind of work is entirely different than in hand filing. These strokes are fewer and of longer duration inasmuch as the work is revolving rapidly and permits of faster cutting. In filing rotating work very nearly all of the cutting edges should be brought into play, that is, one should stroke slowly from one end of the file to the other.

The file should be held in the hands in the same manner as for cross-filing in a vise, as previously described. If the amount of metal to be removed is considerable, the file should be held at an angle, and, if it has single cutting edges, at the angle which presents these edges, flat against the work. The file should be turned over frequently and held at the opposite angle, thus cutting crosswise of the grooves caused by the cutting edges of the file.

If a smooth finish is required and the amount of surface to be removed is nominal, the file should be held at right angles with the work and turned over frequently. It should be swept in even movement from the right to the left of the surface being filed.

It must be remembered that less pressure is required to make the file bite in revolving work than in stationary work. This permits the use of special files for rotating work with concave surfaces which would not suit at all for stationary work. If one does not desire to purchase special machine files, there is an opportunity for using up the old stock which have become so warped and worn that they are no longer suitable for accurate bench work. This applies to the cutting of the radial surface of rotating work. If one is to file a flat rotating surface, such as the end of a disc, one must use an accurate file with a convex surface, the same as for bench work.

Cleaning Files. It is quite important, if one hopes to minimize the purchase of new files, that the ones in use be carefully cleaned after each operation. If the particles of metal removed in the cutting operation become packed into the teeth, this greatly diminishes the cutting powers of the tool. This cleaning may be done to some extent by striking the edge of the file against a solid surface, but such a cure is not a good one. The work can be done more effectively by using a wire brush made for the purpose or by scraping the edge between the cutting surfaces with a thin piece of brass.

Presence of Grease. In filing any metal on the bench, it is well to assure yourself that all grease is removed both from the file and from the work. Grease tends to hinder the file from cutting into the metal. In steel work, where the job is revolving, the file may be frequently oiled, as this measure tends to keep the file clean.

When one is obliged to file objects in inaccessible places about an automobile, there is no rule which can be laid down other than to do the filing in the easiest possible manner. The work required is seldom so extensive that the file will be harmed, no matter how carelessly the work is done.

SOLDERING

General Instructions. It is quite necessary to make use of solder on various parts of the automobile, such as the radiator, the tanks, and the lamps, in spite of the fact that when subjected to stress or vibration such procedure is not considered best. Certain principles must be kept in mind if permanent work is to be accomplished. Cleanliness is a watchword; the surfaces to be joined must be clean, and this cannot be carried too far. Chemically, the metal must be clean as well as free from any oxide. The use of sandpaper or a file to clean and brighten the surfaces is recommended, and this work should be done immediately before the soldering process is begun. It is well to bear in mind that the surfaces of the metal as well as the solder must be hot if a permanent job is to be done. The solder must flow freely, otherwise it will not enter the pores of the metals. Always keep the soldering iron well tinned. Never let it get red hot.

Soldering Flux. The ordinary flux is made by placing zinc clippings in strong hydrochloric acid until no more will dissolve. Some special preparations which are noncorrosive give very good results in soldering. Work soldered with the zinc-hydrochloride as a flux should be thoroughly washed afterwards. A list of the more usual fluxes for the different metals is as follows:

FLUXES FOR SOLDERING

Iron or steel	Treated acid
Tinned iron	Resin or chloride of zinc
Copper to iron	Resin
Iron to zinc	Chloride of zinc
Galvanized iron	Mutton tallow or resin
Copper or brass	Sal ammoniac or chloride of zinc
Lead	Mutton tallow

Light Work. Light work in wire, sheet, and tubes of copper, brass, or iron can be soldered with an ordinary soldering iron, or in a Bunsen flame. The essentials are thorough cleanliness from grease and oxide of the parts and the iron itself, a suitable flux, a good quality of solder, and the iron brought to the right temperature.

Heavy Work. To solder a large tank or radiator, the water should be run out, the place to be soldered should be well prepared, and a large copper soldering iron—sometimes called a "bit"—should be used, preferably one which is automatically heated by a blow lamp. Such a repair is not easy to make, owing to the large cooling surface of the metal. The tank or radiator may have to be taken off the car in order to make the repair conveniently. A soldered joint, of course, will not resist much strain or vibration, and in some cases it is advisable to reinforce the repair by riveting. A brazed joint is much stronger, but brazing is a much more difficult process and should be done only by a skilled operator.

Position of Work. Soldering requires time and judgment. Sufficient time must be given for the heat to flow from the copper to the work. Seams should be held horizontally to prevent the solder from running away from the seam. The area of the joint being soldered must be large, as the elastic limit of solder is much below its tensile strength. Be sure that the soldered joint is not subjected to bending or other stresses that will localize the strain on the solder.

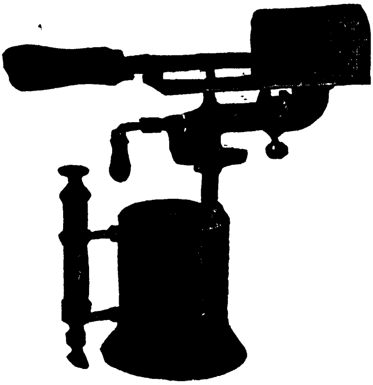


Fig. 9. Soldering Iron Heating Stove
Courtesy of Central Electric Company, Chicago, Illinois

Use of Blow Torch. If two pieces of considerable thickness are to be soldered, the work cannot be done successfully with a soldering iron, as the metal absorbs the heat faster than the iron can supply it; consequently, repairs of this kind are usually accomplished by the use of a blow torch. First the ends of the two pieces to be soldered are tinned—covered with solder separately. Then the two surfaces are put together and the blow torch applied, melting the solder and forming a perfect union. Another method sometimes used is known as sweating, in which the two pieces of metal to be joined are first heated by a blow torch in order that the heat from the actual process of soldering will not be so largely consumed by the metal itself. The more tin there is in solder the stronger it is, but it is harder to melt than that in which lead is the predominating element.

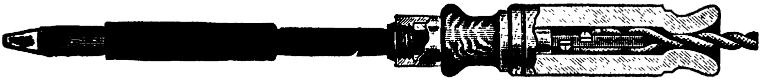


Fig. 10. Electric Soldering Iron
Courtesy of Central Electric Company, Chicago, Illinois

Special Stoves and Irons. Special stoves for heating soldering irons are made and vary in construction. Fig. 9 shows one of the most common forms of soldering-iron heating stoves. Some shops make use of an electric iron for soldering, wherein the temperature of the iron is uniform. Such a tool is shown in Fig. 10.

USE OF MICROMETERS

Principle of Operation. In case measurements are required to be more accurate than can be obtained with the ordinary calipering devices, the micrometer caliper, as shown in Fig. 11, is used. The accuracy of its measurements is determined, not by direct setting to two lines, but by finely dividing the pitch of the measuring screw and furnishing means for reading these subdivisions. It is a registering as well as an indicating caliper, and thus serves the purpose of a common caliper in combination with a rule, but with a much greater degree of accuracy.

Essentially, the micrometer caliper consists of a crescent-shaped frame carrying a hardened steel anvil *B* at one end and a nut of fine pitch at the other, the axis of the nut being at right angles to the face of the anvil. The outside of the nut *A* forms a projection beyond the crescent that is called the barrel. The measuring screw consists of a finely pitched screw to fit the nut, combined with a measuring point *C*, having a face parallel with that of the anvil. To the outer end of this screw is firmly attached a thimble *D*, which fits closely over the barrel. The edge of this thimble is beveled at *A* so that graduations placed on the edge come very close to the barrel. A reference line is drawn on the barrel, parallel to its axis and graduated to represent the pitch of the screw. The chamfered edge of the thimble is so divided that the movement of one division past the reference line on the barrel of the instrument indicates a movement of the measuring point of .001 inch.

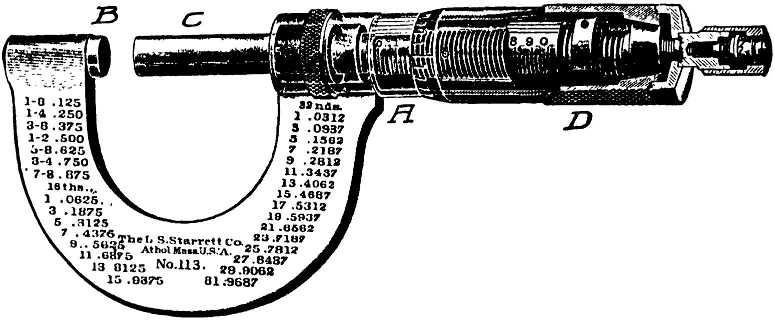


Fig. 11. Transparent View of Micrometer Caliper with Friction Stop
Courtesy of L. S. Starrett Company, Athol, Massachusetts

To illustrate: if the pitch of the measuring screw is .01 inch, there should be ten divisions on the thimble; if .02 inch, twenty divisions; if .04 inch, forty divisions. Most measuring screws have a pitch of .025 inch and these are the type usually used, every fourth dimension on the barrel being lengthened and numbered to indicate tenths of an inch.

How to Use Micrometer. When using the micrometer caliper, it should not be set to the size desired and pushed over the work, but should first be opened, then screwed down until the measuring point *C* and the anvil *B* are in contact with the work. The size may then be read by taking the number of scale divisions on the barrel and adding the value of the parts on the thimble corresponding to the reference line on the barrel. The proper degree of pressure to be applied to the screw is acquired only after extended practice, and some manufacturers place a friction device on the thimble, as shown at the extreme right of Fig. 11, so that undue pressure cannot be exerted.

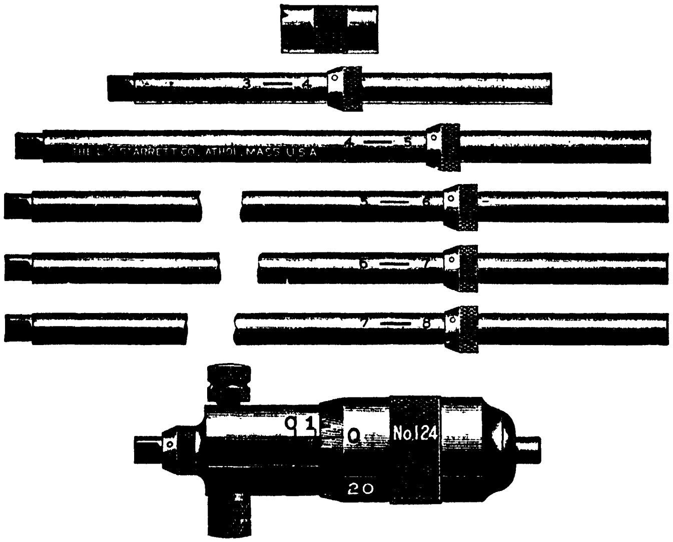


Fig. 12. Inside Micrometers
Courtesy of L. S. Starrett Company, Athol, Massachusetts

Value of Micrometer. The value of the micrometer caliper cannot be impressed too strongly upon the user. Not only does it show when work is too large or too small, but it gives the exact amount of variance in desired measurements. It is a distinct improvement over the caliper and enables the user to work with accuracy. The 1-inch size is the most common, but micrometers may be obtained in all sizes up to 20 inches. Using the micrometer for inside measurements is not the usual application, but it is easy to arrange and makes a very simple instrument, as shown in Fig. 12.

Reading the Micrometer. All readings are in thousandths. The usual micrometer has forty threads to the inch and the thimble has twenty-five divisions on its circumference. The barrel is divided to correspond to the pitch of the screw with each fourth division numbered. In reading, first note the highest numeral visible on the barrel and express it as so many hundred thousandths; then read the short divisions on the barrel, calling the first division twenty-five thousandths, or .025; the second, fifty thousandths, or .050; and the third, seventy-five thousandths, or .075. Now read the number indicated on the thimble, that is, the number that has passed the line running lengthwise. Add this reading to the readings of the short divisions. The result of adding the highest numeral visible on the barrel, which is expressed in hundred thousandths, the short divisions on the barrel and the number indicated on the thimble, give the distance from the anvil to the measuring point. If the micrometer caliper is a good one, we may be sure the distance does not exceed or fall short of the figures given by .001 inch.

DRILLING

Types of Drills. There are two kinds of drills which are found in modern repair shops, the *twist* drill and the *flat* drill. The former is the one which is used in practically every kind of work, although the flat drill has its function in certain operations.

Flat Drills. The flat drill, Fig. 13, is the simplest and, incidentally, the oldest type; until the invention of the twist drill, the flat drill was used for all drilling work. It is made from a piece of round stock, on the end of which are forged thin lips which are ground with two cutting edges, the edges being on the V-shaped end of the tool. For the performance of accurate work the flat drill is a poor tool, its field being in rough drilling of extremely hard metals. As a deep hole drill it is useless because it does not free itself of chips. For drilling out a cored hole in an iron or steel casting preparatory to boring, the flat drill is superior to the twist drill, inasmuch as this work is very injurious to the twist drill because of scale and sand which is bound to be within the core.

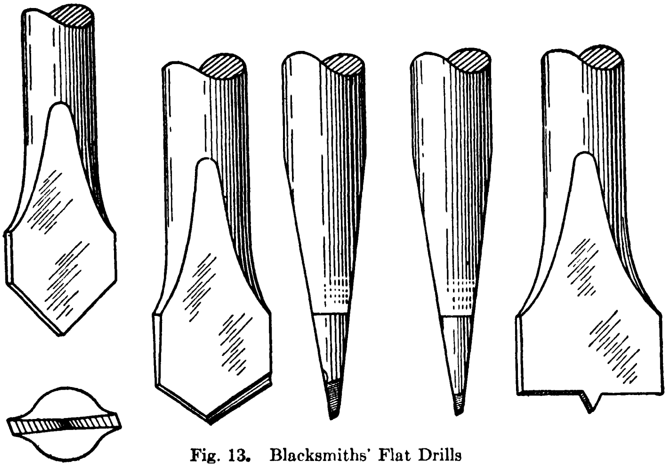


Fig. 13. Blacksmiths' Flat Drills

Twist Drills. In small drill sizes, the twist drills come in straight shanks, Fig. 14, while in the larger sizes, taper shanks, Fig. 15, are most generally used. The shank is the part of the drill which fits into the holding device whether it be the chuck of a drill press or a bit.

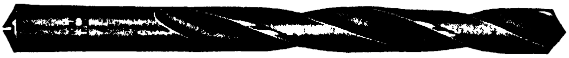


Fig. 14. Typical Twist Drill
Courtesy of Union Twist Drill Company, Athol, Massachusetts

As will be seen from the illustrations, a twist drill is fluted or grooved in spirals which follow the direction of rotation of the drill. These flutes serve to carry the chips from the cutting edges which, as is the case with the flat drill, are on the V-shaped end of the tool; the flutes also act as a channel through which lubricant may be directed to the cutting edges. For small drills the blanks are usually made from steel wire and for large drills from round steel stock. The flutes are milled into the tool.

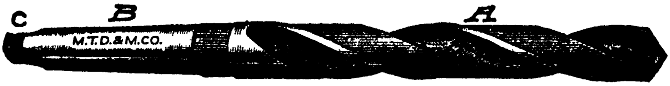


Fig. 15. Taper Shank Twist Drill
Courtesy of Morse Twist Drill Company, New Bedford, Massachusetts

TABLE I
Morse Tapers

No. of Taper	Taper per Foot	Smallest Drill Using Each Taper (in.)	Largest Drill Using Each Taper (in.)
1	.605	$\frac{1}{8}$	$\frac{19}{32}$
2	.600	$\frac{39}{64}$	$\frac{29}{32}$
3	.605	$\frac{59}{64}$	$1\frac{1}{4}$
4	.615	$1\frac{17}{64}$	2
5	.625	$2\frac{1}{64}$	3
6	.634	Special	Special

Grinding Drills. Great care must be exercised in grinding the twist drill. The angle of lip clearance—the lips being the cutting edges—should be greater at the center than at the outside of the lips. This is to permit the part of the drill which first touches the metal to be drilled to bite in. The usually accepted angle is about 12 degrees, as shown in Fig. 16. If the difference in the angle on the lips is too great, the drill bites too quickly, which may result in tearing off or chipping the cutting edges. If, on the other hand, the angle is too small, the cut is slow, and the drill will consequently heat excessively. Although there are a number of drill grinders on the market which do satisfactory work, the use of drills in a motor-car repair shop is seldom sufficient to warrant the purchase of one. After a little experience with drilling, one can determine the angles which give the best results by the "feel" of the drill and the dull drills can be ground accordingly.

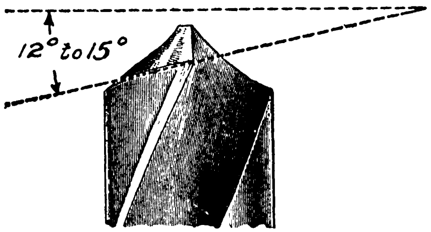


Fig. 16. Cutting Edge Clearance

Sizes of Drills. The taper-shank drill is made in six sizes and the shank has the Morse taper. The exact taper and the limiting sizes for which each drill is generally used are given in Table I.

These taper-shank drills are carried as regular stock in all sizes by 64ths from $\frac{1}{8}$ to $2\frac{1}{2}$ inches and by 16ths from that size up to 3 inches. If one needs a drill larger than 3 inches, which would surely be a rare occasion in garage work, that drill would have to be made to order.

The wire gage sizes run by number rather than by dimensions, ranging from No. 80, the smallest twist drill made, up to No. 1.

TABLE II

S.A.E. Standard Taps and Drills

Sizes of Taps	Sizes of Drills
1/4 inch×28 threads.........	7/32 inch
5/16 inch×24 threads.........	17/64 inch
3/8 inch×24 threads.........	21/64 inch
7/16 inch×20 threads.........	3/8 inch
1/2 inch×20 threads.........	7/16 inch
9/16 inch×18 threads.........	1/2 inch
5/8 inch×18 threads.........	9/16 inch
11/16 inch×16 threads.........	39/64 inch
3/4 inch×16 threads.........	43/64 inch
7/8 inch×14 threads........	25/32 inch
1 inch×14 threads.........	29/32 inch
1 1/8 inch×12 threads....... ..	1 1/64 inch
1 1/4 inch×12 threads.........	1 9/64 inch
1 3/8 inch×12 threads.........	1 17/64 inch
1 1/2 inch×12 threads.........	1 25/64 inch

The above tap drills allow a thread within 1/64 inch of full thread.

Speed of Drills. The speed at which drills are driven has an important bearing on their wearing quality. Of course small drills can revolve faster than large drills. The proper feeds for drills—which means the speed of cutting as regards depth—varies with the kind of metals which are being cut. A very small drill can cut .02 inch per revolution in cast iron; a large one can cut no more than .005 inch.

Lubrication. For cutting malleable iron or steel the drill must be continually flooded with oil, while in cast-iron, aluminum, and brass drilling, the cutting is performed dry.

TAPPING

Standard Threads. Tapping is that process of cutting on the walls of a drilled hole a series of threads into which a screw is to be fitted. In practically every instance in motor-car practice, the standard taps and drills specified by the Society of Automobile

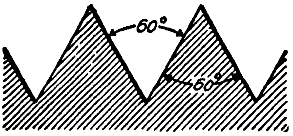


Fig. 17. Section of V-Thread

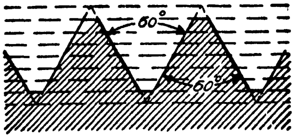


Fig. 18. Section of United States Standard Thread

TABLE III

Drill Sizes for Standard Threads

Size Screw	No. of Threads	Size of Drill			Size Screw	No. of Threads	Size of Drill		
		U.S.S.	V	W			U.S.S.	V	W
1/4	24	.201	.196	.202	15/16	9	.808	.790	.810
1/4	20	.191	.184	.192	1	8	.854	.832	.856
5/16	18	.248	.239	.249	1 1/16	8	.917	.894	.919
3/8	16	.302	.293	.303	1 1/8	7	.957	.932	.960
7/16	14	.354	.345	.355	1 1/4	7	1.082	1.057	1.085
1/2	13	.409	.399	.410	1 3/8	6	1.179	1.144	1.182
1/2	12	.402	.391	.403	1 1/2	6	1.304	1.269	1.307
9/16	12	.465	.453	.466	1 5/8	5 1/2	1.412	1.372	1.416
5/8	11	.518	.506	.520	1 5/8	5	1.390	1.347	1.394
11/16	11	.581	.568	.583	1 3/4	5	1.515	1.472	1.519
3/4	10	.632	.618	.634	1 7/8	5	1.640	1.597	1.644
13/16	10	.695	.680	.697	1 7/8	4 1/2	1.614	1 566	1.619
7/8	9	.745	.728	.747	2	4 1/2	1.739	1.691	1.744

The above sizes give an allowance above the bottom of the thread on sizes ¼ to 2, respectively, varying as follows: for V-threads, .010 inch to .055 inch; for U.S.S. and Whitworth threads, .005 to .027 inch.

These are found by adding to the size at the bottom of the thread one-quarter of the pitch for V-threads and one-eighth of the pitch for U.S.S. and Whitworth, the pitch being equal to 1 inch divided by the number of threads per inch.

In practice it is better to use a larger drill if the exact size called for cannot be had.

Engineers, Table II, will be used. Drill sizes of U.S.S., V-Standard, and Whitworth threads are given in Table III.

The V-thread is shown in Fig. 17. The U.S.S. thread, Fig. 18, is the same as the V-type except that the tops are cut off and the roots, or bottoms, of the threads are filled in. It is more cheaply produced than the V-thread and does not cut so deeply into the stock, leaving a stronger root. In the Whitworth, or English Standard threads, the tops of the threads are rounded off and the roots are concave. In the S.A.E. Standard thread the U.S.S. principle of construction is used.

Taps. The tool used to cut internal threads is known as a tap, external threads being cut with a die. There are hand taps and machine taps. The difference is principally in the shank. Hand taps have round shanks which are milled square on the end to receive the tap wrench. Three types of taps, called the taper, plug, and bottoming taps, Fig. 19, generally constitute a set.

Taper Tap. The taper tap has straight sides on the point end for a distance of one-fourth the diameter of the tap. The teeth at the shank end are parallel for a length equal to the diameter of the tap.

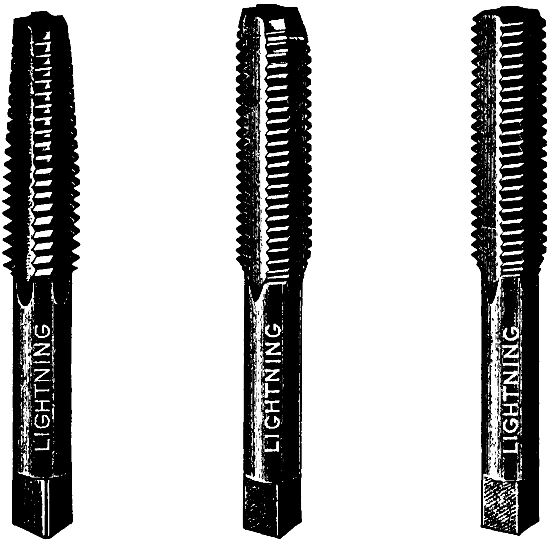


Fig. 19. Types of Hand Taps: Left—Taper Tap; Center—Plug Tap; Right—Bottoming Tap
Courtesy of Wiley & Russell Manufacturing Company, Greenfield, Massachusetts

The teeth between these parallel teeth and the straight sides are tapered. This gives a graduated cutting depth for the teeth, the front teeth cutting less stock than the back. This tap is best suited for starting a thread, but unless the hole goes entirely through the piece that is being tapped there will, of course, be a space in the bottom of the hole equal to one-fourth the diameter of the hole which will not be threaded.

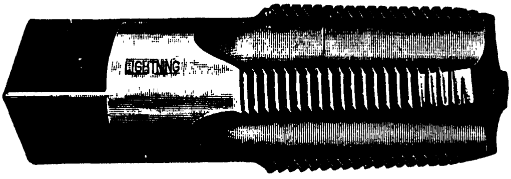


Fig. 20. Wiley & Russell Pipe Tap

Plug Tap. The plug tap is most commonly used. It has three teeth on the end, tapered off so that while useful to start the thread, they will bottom a hole sufficiently to take a bolt with a tapered or round end.

Bottoming Tap. The bottoming tap is useful to finish out the thread started by a taper tap when the hole does not go entirely through the piece.

There is frequent use in garages for pipe-plug taps, Fig. 20. As will be seen, they are more stocky than bottoming taps, and, of course, have a taper throughout the surface of the cutting area to take care of the taper threads required by a pipe plug.

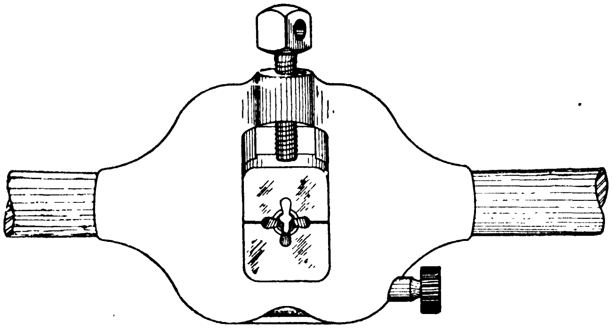


Fig. 21. Threading Die Holder

Tapping Process. It must be remembered in using taps that, because of the nature of the work they are called upon to do, they are tempered hard and the cutting edges are very brittle; they must, therefore, be handled with great care. In hand tapping the process simply cannot be rushed; the tap must be turned slowly forward about half a turn and then back, advancing the wrench a little each time with an even stroke. As previously mentioned, a wrench must be used which fits over the square end. The pressure of both hands operating the opposite handles of the wrench must be even.

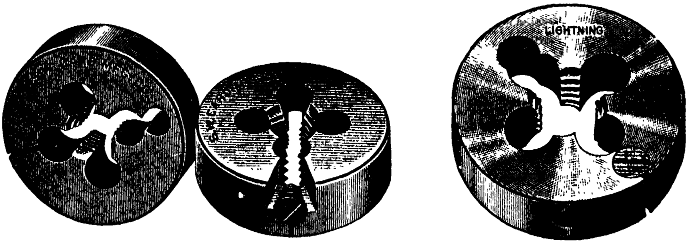


Fig. 22. Two Forms of Adjustable Dies; Left—Card Die with End Taper Screw; Right—Wiley and Russell Die with Side Taper Screw

Dies. There are two kinds of dies. One is the split type which requires several settings before the thread is completed and the other which completes the work in one operation. The first kind is shown in Fig. 21, the assembly consisting of a stock or wrench in which the cutting die is held. These dies, for a specified size, may be opened up until the cutting edges will slide over the work and then, when fully closed, will give the completed thread of the correct dimension.

Dies which complete the thread in one operation are made adjustable for wear. They are made up in a solid round piece with one side cut away with a slot, as shown in Fig. 22, so that wear may be taken up by means of a taper-set screw.

Oil should always be used in abundance on taps or dies. When one is threading steel or malleable iron, it is well to turn the die back after every three or four turns forward.

In cutting threads with taps and dies in the lathe, the speed with which the tools may be operated is a very important consideration. Cast iron, brass, and aluminum can be threaded at a much higher speed than steel, but a tap or die must not be run as fast as a drill. A speed of 10 feet per minute in hard stock is a fair average.

REAMING

Function of Reamer. Reamers find their place in the production of round, straight, and smooth holes, uniform in diameter, as required in the construction of accurate machinery, requirements which a drill cannot always be relied upon to meet. The reamer is a sizing tool having two or more teeth either parallel or at an angle with each other, the latter forming what is known as a taper reamer. These

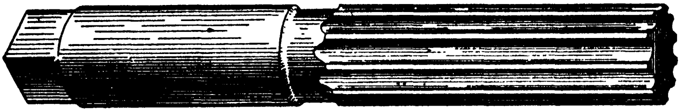


Fig. 23. Solid Hand Reamer

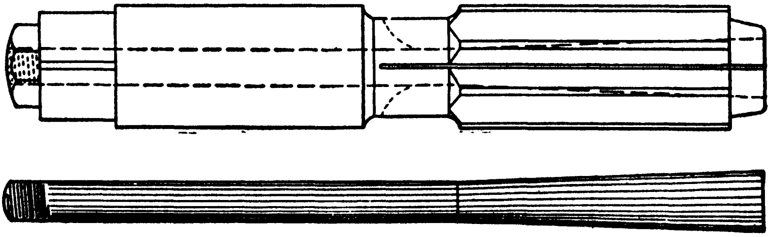


Fig. 24. Expanding Reamer and Arbor

teeth may be either straight or spiral, a spiral tooth producing a shearing cut and a straight tooth a square cut.

The construction of reamers divides them into two general classes—solid, and adjustable, or expansion, types. A solid reamer, Fig. 23, has a shank and teeth made from a single piece of tool steel. All taper reamers come under the solid class. The expansion reamer is a built-up tool, the usual form consisting of a shank and head, with an expanding arbor passing down through the center, Fig. 24. As adjustment to compensate for wear only is attempted, the amount of expansion is small.

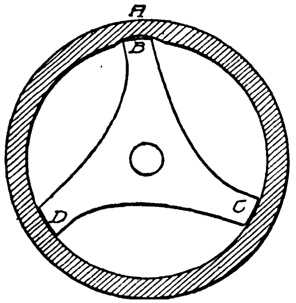


Fig. 25. Diagram Showing Action of Three-Lipped Reamer in Irregular Hole

Number of Teeth. Number, form, and spacing of teeth are important considerations. Reamers having fewer than five teeth are not to be used where an accurate cylindrical shape is desired. A reamer having three teeth cannot be depended upon to produce round holes, inasmuch as any irregularity in the hole being reamed affects the cutting of the tool. For example, suppose a depression *A*, Fig. 39, exists in the drilled hole; if tooth *B* comes to this point and drops in, the cutting of *C* and *D* is decreased, thus producing a hole that is not round. The same effect to a lesser degree is shown in Fig. 26. When the cut is relieved at *A*, the pressure of the cut *C* will crowd the tool toward *E*. Since the pressure of the cut at *B* and *D* balance each other, any decrease of the cut at *C* causes an increase at *D*, and *B* and *C* will overbalance *D*, the body of the reamer moving an appreciable distance toward *E*. With five or more teeth this effect practically disappears. The more cutting edges, the more smoothly will the reamer work. The construction of adjustable reamers does not admit of as many teeth as can be formed on a solid reamer, yet the advantage of adjustability to a certain extent offsets this.

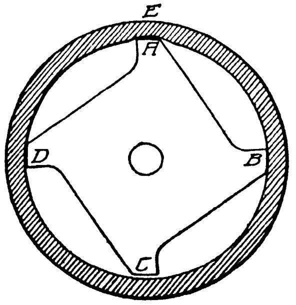


Fig. 26. Diagram Showing Action of Four-Lipped Reamer in Irregular Hole

Where reamers have a number of teeth equally spaced, they do not produce so good results as those having an odd number of teeth. In the former, the teeth fall opposite each other, causing greater tendencies to vibration, and in the case of reaming irregular holes, the greatest cut will be carried on two opposite teeth. With an odd number of teeth the greatest cut must be carried on at least three teeth. Extensive use of reamers having an even number of teeth irregularly spaced is common. This gives practically the same effect as having an odd number of teeth.

Clearances. Grinding of the clearance on top of the tooth is an important point in the construction of a reamer. The clearance should be sufficient properly to relieve the cutting edge, as shown in Fig. 27. If too great a clearance is given, the tooth will be weak and chatter in the work. As is frequently produced, the cleared surface is slightly concave, the amount depending upon the diameter of the emery wheel used in grinding it. As a plane surface is desirable, a wheel of large diameter which gives approximately such a surface should be employed, or better still, the face of a cup emery wheel which gives a straight clearance.

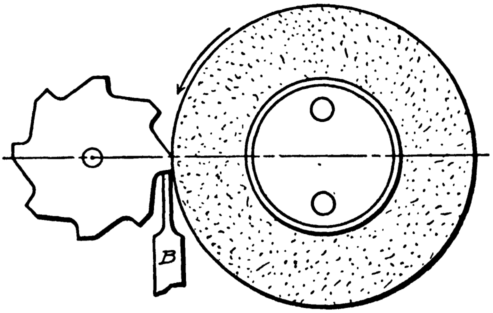


Fig. 27. Diagram Showing Method of Grinding Reamer for Clearance

Clearance Angle. Clearance angle will depend largely on the distance the axis of the emery wheel is set back of the axis of the reamer. In no case must the wheel come in contact with the front face of the tooth being ground on the one next behind, and the guiding finger which steadies the reamer must always bear against the front face of the tooth being ground. When the diameter of the reamer is large and the pitch of the teeth so small that the necessary clearance cannot be given except by using too small an emery wheel, the wheel can be mounted on an axis at a considerable angle to the axis of the reamer. This produces a plane surface, but because of the wear of the emery wheel, it is not so satisfactory as the use of the cup wheel.

The wheel must be so placed as to cut its entire width, otherwise it will be grooved and the cutting edges of the tooth rounded off.

Characteristics of Hand Reamings. Reamers for hand use are made in two lengths, what is known as the *short* reamer being considerably shorter both in the flute and in the shank than the regular, or *jobber's*, reamer. The diameter of the point is about $\frac{1}{64}$ inch under size, the tool tapering to exact diameter at about one-fourth of the length of the tooth from the point. The remainder of the teeth are ground nearly parallel, the diameter of the shank end being from .0005 to .00075 inch small. This slight taper counteracts the tendency that all reamers have to ream a hole slightly over size at the top, which is due to the tool remaining longer in contact with the wall of the hole at the top than at the bottom. The limit of error allowed in their manufacture does not exceed .00025 inch.

Kinds of Reamers. The *spiral-fluted reamer* always is cut with a left-hand spiral. It gives a smooth shearing cut and is especially valuable for machine reaming on centers as it does not tend to draw into the work and off from the center. They are also made in shell and taper form.

Fig. 28. Reamer with Inserted Blades
Courtesy of Brown and Sharpe Manufacturing Company, Providence, Rhode Island

A *fluted chucking reamer* with a taper shank is not unlike a hand reamer. The teeth are short and slightly tapered at the point, which facilitates starting when used against the dead center of a lathe.

The *three-flute chucking reamer* has a long shank, and the fluted portion is ground cylindrically true and is especially adapted to the reaming of deep-cored holes.

Those classes of adjustable-blade reamers in which each blade is set out independently, Fig. 28, should be reground after each adjustment, as it is almost impossible to set the blades out equally. In using a reamer it should be turned continually forward. Never turn it backward for withdrawal, as this is likely to injure the tool. Oil should be used freely in reaming steel or wrought iron. Cast iron and brass are usually reamed dry. A small amount of oil, however, frequently improves the quality of work in these metals.

FITTING TAPER PINS

Determining Amount of Taper. In order to set the slide rest of the lathe at the proper angle for boring or reaming any degree of taper, measure the diameter of the circular rest-seat, Fig. 29, and describe a circle of that diameter on a flat surface, marking the center of the circle and drawing a radial line *AH*, Fig. 30; mark off on *AH* a distance *AB* equal to the diameter of the small end of the taper hole to be bored and draw the line *AG* at right angles to *AB* and of a length equal to the length of the taper to be bored. Draw *GD* parallel to *AB* and of a length equal to the diameter of the large end of the taper. Connecting *D* and *B*, the distance *EF* measured on the circumference of the circle between the lines will equal the amount that the rest must be swiveled to cut the desired taper.

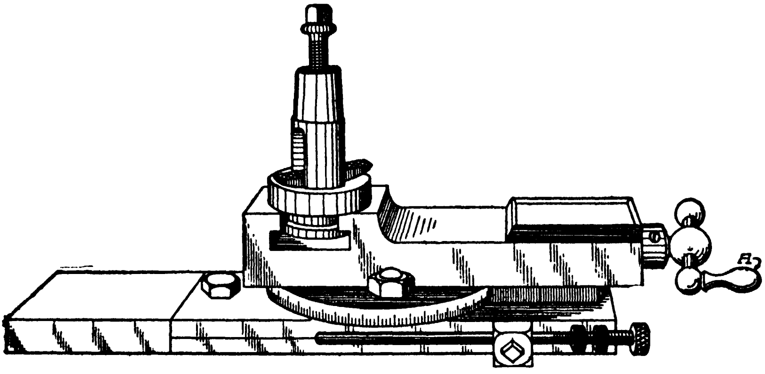


Fig. 29. Compound Tool Slide Rest

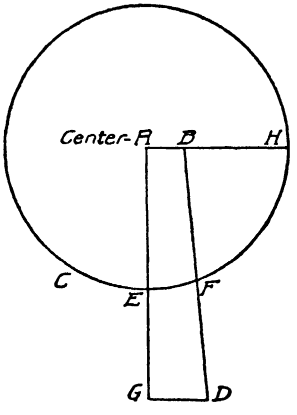


Fig. 30. Diagram for Determining Slide Rest Setting to Give Certain Taper

Reamers and Taper Pins Available. The Pratt & Whitney Company makes standard taper reamers with a taper of $\frac{1}{16}$ inch per foot and diameters from $\frac{1}{4}$ inch up; also 4-inch length of flute up to 2 inches in diameter; finally they make 18-inch length of flute, diameters advancing by 16ths and 32nds. The Pratt & Whitney standard taper-pin reamers taper $\frac{1}{4}$ inch per foot and are made in fifteen sizes.

Brown & Sharpe make eighteen sizes of tapers ranging from 0.20 inch to 3 inches in diameter at the small end; taper 0.5 inch to 1 foot, except the number 10, which is 0.5161 inch per foot.

The Jarno taper is 0.05 per inch, or 0.6 inch per foot. The number of the taper is its diameter in tenths of an inch at the small end, in eighths of an inch at the large end, and the length in halves of an inch. Thus, No. 3, Jarno taper is 1½ inches long, 0.3 inch in diameter at the small end and ⅜ inch in diameter at the large end.

HAND KEYSEATING

Hand keyseating is that process of cutting a groove into a piece of metal into which a key will fit accurately. The need of accuracy in keyseating is the great drawback to the hand method inasmuch as it is a tedious job to cut a true seat with a chisel.

Keyseating Process. The roughing out of the keyseat is done by chipping, a process already described. The first thing to determine is the size of the keyseat, and this is obtained from the S.A.E. table of standard sizes of keyseats, Table IV. It is well to have a chisel with a cutting surface about ⅛ inch smaller than the width of the keyseat to be cut, although with a large keyseat a smaller chisel will do the work but with somewhat more cutting. A cape chisel, Fig. 4, is the tool used for keyway cutting.

Laying Out the Keyway. The next operation is to very carefully mark off the keyway with scratched lines on chalk, the distance between the lines to be from $\frac{1}{16}$ to $\frac{1}{32}$ inch less than the width of the key. Use these lines to guide the chisel and cut the keyway to a depth approximately within $\frac{1}{16}$ inch of the depth of the finished keyway. One must always leave sufficient stock on the sides and bottom of the keyway for an accurate finish filing.

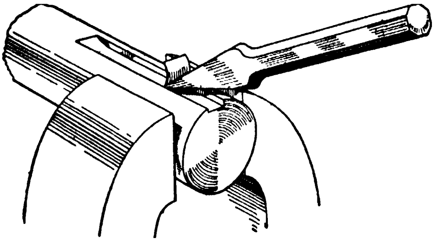


Fig. 31. Chipping Keyseat in Round Shafting

Chipping. The work is held in a vise, and the chipping is done by grasping the chisel firmly with the left hand, holding the cutting edge to the work and striking the head of the chisel with the hammer, Fig. 31. The eyes must be kept on the cutting edge of the chisel to

TABLE IV

Standard Sizes of Keyseats

For straight keys, height of keyseat $= D$
For feather keys $D = \frac{1}{2}A$
Keyseat in shaft same depth as D in small end
Standard Taper $= \frac{1}{8}$ inch per foot.

Size of Bore (in.)	A Width (in.)	D Smallest Height (in.)	Size of Bore (in.)	A Width (in.)	D Smallest Height (in.)
1 to $1\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{32}$	$3\frac{11}{16}$ to $3\frac{7}{8}$	$\frac{15}{16}$	$\frac{5}{16}$
$1\frac{3}{16}$ to $1\frac{3}{8}$	$\frac{5}{16}$	$\frac{7}{64}$	$3\frac{15}{16}$ to $4\frac{1}{8}$	1	$\frac{11}{32}$
$1\frac{7}{16}$ to $1\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$4\frac{3}{16}$ to $4\frac{3}{8}$	$1\frac{1}{16}$	$\frac{11}{32}$
$1\frac{11}{16}$ to $1\frac{7}{8}$	$\frac{7}{16}$	$\frac{9}{64}$	$4\frac{7}{16}$ to $4\frac{3}{4}$	$1\frac{1}{8}$	$\frac{3}{8}$
$1\frac{15}{16}$ to $2\frac{1}{8}$	$\frac{1}{2}$	$\frac{11}{64}$	$4\frac{13}{16}$ to $5\frac{1}{4}$	$1\frac{1}{4}$	$\frac{27}{64}$
$2\frac{13}{16}$ to $2\frac{3}{8}$	$\frac{9}{16}$	$\frac{3}{16}$	$5\frac{5}{16}$ to $5\frac{3}{4}$	$1\frac{3}{8}$	$\frac{29}{64}$
$2\frac{7}{16}$ to $2\frac{5}{8}$	$\frac{5}{8}$	$\frac{13}{64}$	$5\frac{13}{16}$ to $6\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$
$2\frac{11}{16}$ to $2\frac{7}{8}$	$\frac{11}{16}$	$\frac{15}{64}$	$6\frac{5}{16}$ to $6\frac{3}{4}$	$1\frac{5}{8}$	$\frac{17}{32}$
$2\frac{15}{16}$ to $3\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{4}$	$6\frac{13}{16}$ to $7\frac{1}{4}$	$1\frac{3}{4}$	$\frac{19}{32}$
$3\frac{3}{16}$ to $3\frac{3}{8}$	$\frac{13}{16}$	$\frac{17}{64}$	$7\frac{5}{16}$ to $7\frac{3}{4}$	$1\frac{7}{8}$	$\frac{5}{8}$
$3\frac{7}{16}$ to $3\frac{5}{8}$	$\frac{7}{8}$	$\frac{19}{64}$	$7\frac{13}{16}$ to $8\frac{1}{2}$	2	$\frac{21}{32}$

watch the progress of the work. The beveled side of the chisel is the guiding surface and this should be held at a very slight angle with the surface of the work that is being cut. Of course, to increase or decrease the amount of the cut, it is only necessary to raise or lower the chisel. If the hand is carried too low, the tool will run out before the end of the cut; while if the hand is carried too high, the chisel will gouge into the stock and make the progress of the work slow. In steel, malleable iron, and cast iron, the depth of the cut should vary from $\frac{1}{16}$ to $\frac{1}{8}$ inch, but should never be greater than the latter figure.

Chipping Malleable Iron and Steel. When chipping malleable iron or steel, one should keep on the work bench a piece of waste or cloth saturated with oil. After each complete cut is made through the work, the chisel should be rubbed in this waste or cloth. This lubricates the cutting edges and prolongs the life of the chisel.

Finish Filings. It is in the finish filing that the greatest accuracy must be observed. It is not advisable to attempt cutting keyways to an accurate size by the use of inside calipers or other measuring instruments; it is best to have at hand the key which is to be fitted into the keyway. As the work of filing progresses, test the key in the keyway at frequent intervals. The sides and bottom should be filed at the same time, and it is quite important that the proper width of file be obtained. One should so file the keyway that the bottom and sides will be cut down to the proper size at about an equal rate. The key must not be a loose fit but a press fit within the slot.

TABLE V

Proportions for Riveted Steel Plates with Iron Rivets

	Inch	Inch	Inch	Inch	Inch
Thickness of plate......	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
Diameter of rivet........	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$
Diameter of rivet hole....	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
Pitch—single riveting.....	2	$2\frac{1}{16}$	$2\frac{1}{8}$	$2\frac{3}{16}$	$2\frac{1}{4}$
Pitch—double riveting...	3	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{1}{2}$

Woodruff Keys. Although it is a very difficult and time-consuming task, it is possible to cut Woodruff keys with a chisel. These are "half moon" keys, the radial surface serving to lock the key into the seat after the matching keyways are fitted over it. The cut and try process is the only method to use in fitting Woodruff keys. Have the key at hand and chip the concave keyway, using the key as a pattern.

Cold=Riveting Metals. Rivets are used to hold together two or more pieces of sheet metal and are employed in the assembly of frames, the supporting of spring hangers, etc. Table V gives the proportions for riveted joints in steel plates with iron rivets.

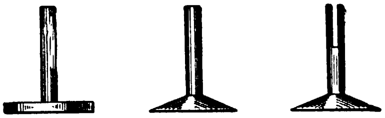


Fig. 32. Types of Rivets for Brake Linings

Cold riveting can be applied to work where accuracy is not a requisite and the rivets are of small size, as in sheet metal work.

Hot=Riveting Metals. For hot-riveting work there are two general classes of rivets used: countersunk rivets and flush rivets, Fig. 32. Flush rivets are used to support the spring hangers to the frame and in riveting cross-members to the frame, etc. Countersunk rivets are used cold in brake lining facing and clutch facing, as previously described, and in joining pieces where clearance is a factor, as in riveting the ring gear to the differential case flange.

Rivet Set. In heading large rivets, it is always advisable to use a rivet set, and in the case of riveting the ring gear to the differential case flange this tool is essential. The rivet set is a tool with a spherical depression in the end. When this spherical depression is applied to the shank end of a rivet and the rivet set is hammered, the end of the rivet will be headed over in a nicely rounded head. It is the only way that accurate riveting can be accomplished.

Installing New Ring Gear. Usual rivet sizes for use in fastening the ring gear to the differential housing flange are $\frac{1}{4}$, $\frac{5}{16}$, and $\frac{3}{8}$ inch. The rivets used are round-headed or countersunk and are made of iron. To do a good job of installing a new ring gear proceed as follows:

Removing Old Gear. The first thing to be done is to remove the old gear. This is done by cutting off the rivet heads with a sharp chisel in the manner shown in Fig. 3. If the rivet is countersunk, the head may have to be drilled out to remove it. After the gear is off, go over the surface of the differential housing flange with a file—especially over the rivet holes—to remove any burrs or irregularities in the metal which would cause an untrue seat and thus throw the ring gear out of line. Do the same thing on the face of the ring gear which is to fit against the differential housing flange.

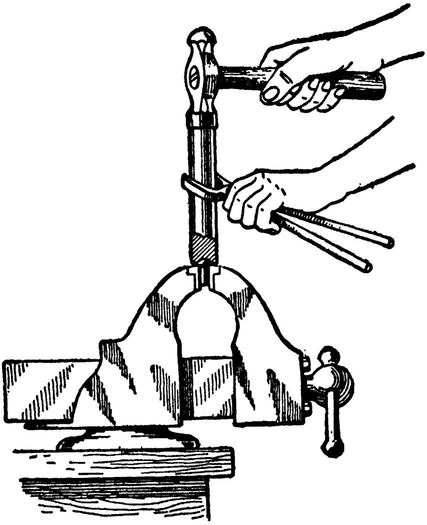


Fig. 33. Easily-Made Type of Rivet Set

Heating Rivet. Although this job may be done by cold riveting, the hot method is a stronger and truer assembly because it permits more accurate seating and firmer fastening of the rivets. The rivets should be of such a length that they will extend beyond the flange a distance equal to one and one-half times the diameter of the rivet. The rivets should be placed through the flange and gear in consecutive order but alternating in direction; that is, the head of one rivet should go through in one direction and the head of the rivet next to it in the other direction.

One of the best methods of heating the rivets is by means of an oxy-acetylene flame, although they may be heated in a forge as well. The rivets must be put into the holes red hot, as they are more easily headed over, and, in addition, the shrink in the rivets as they cool draws the pieces closer together. The constant hammering in forming the head thoroughly fills the hole.

Making Rivet Set. If one does not desire to purchase a rivet header, it is not hard to make one. One of the simplest ways is as follows: Procure a bar of round steel about twice the diameter of the head of the rivet. Fasten one of the rivets in a vise with the shank within the vise and the under side of the head flat against the top of the vise jaws. Now heat one end of the bar to a white heat and drive the heated end against the round rivet head, thus making a depression in the end of the bar, Fig. 33. It will probably be necessary to reheat the bar two or three times, using a new rivet each time, to get the depression deep enough. This depression should be of such depth as to take in the entire head of the rivet. Another method is to drill the depression into the end of the bar, thus giving a V-shaped depression. Such a depression will serve nearly as well as the round one for the work at hand.

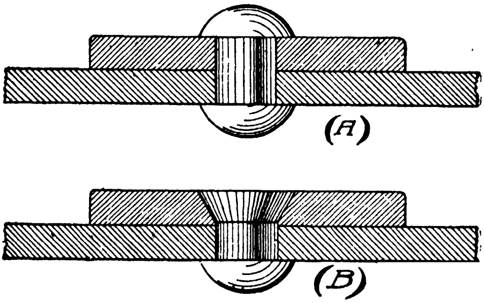


Fig. 34. Section of Rivets in Place

Heating the Rivet. It is now assumed that one has rivets, red hot, in the forge, a rivet set of the proper size, and that an anvil or a block of steel or iron, upon which the riveting may be done, is available. Extract one of the rivets from the forge with the tongs and insert it quickly into the rivet hole. It is imperative that the work be done quickly, so that the final heading is completed before the rivet has had a chance to cool. The head of the rivet is dropped down against the anvil or block of iron or steel. With the assembly held firm against the anvil or block, place the rivet set over the shank of the rivet and hammer with quick light strokes against the other end of the rivet set with a fairly heavy machinist's hammer. Convenience and quick work demand that this be made a two-man job, one to hold the work and the other to do the riveting. In shaping the head, oscillate the rivet set in the hand so that the head will be evenly rounded on all sides. A properly shaped rivet head should be very nearly the same shape as the head, which was a part of the rivet in its original form, as shown in Fig. 34 A. A well-rounded head is stronger than one which is more or less flat and which spreads over a larger area. In Fig. 34 B is shown the section of a countersunk head joint.

SHOP INFORMATION

PART II

FORGING

Forging Equipment. *Forges.* Many of the jobs in a repair shop require the use of a forge, two kinds being necessary for all well-equipped shops. Forging and welding are easily cared for by the power-driven blower forge, Fig. 35. This type of forge is made of steel and the medium size is best for automobile repair shop work. For brazing, melting babbitt metal, hardening, tempering, annealing, and heating soldering irons, it is best to use a gas forge that takes its air from the tank of the air-compressor outfit and its gas from the regular city or town mains. Portable gasoline forges, Fig. 36, are obtainable and work equally well. It is well

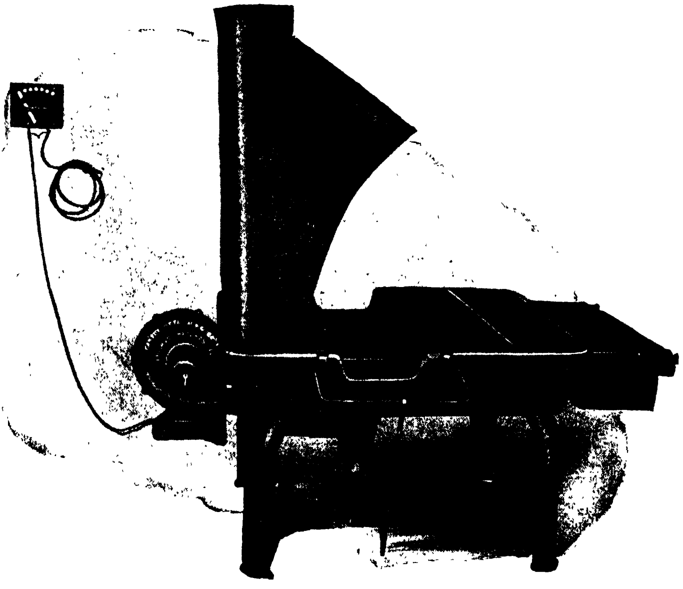


Fig. 35. Modern Motor-Driven Forge
Courtesy of Canedy-Otto Company, Chicago, Illinois

to have also a small hand torch, Fig. 37, for use in smaller brazing or soldering jobs.

It is well to set up these two necessary forges with a bench between them. The bench should have a large drawer and a good vise attached to it, and will be found useful both in brazing and soldering processes; the drawer can be divided into compartments, one to hold the blacksmith tools and the other the soldering irons and sheet-metal tools. The vise will come into use innumerable times at either forge.

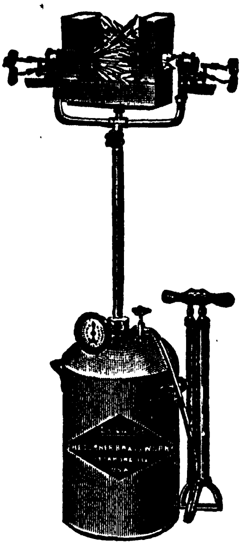


Fig. 36. Double-Jet Brazer
Courtesy of Turner Brass Works, Chicago, Illinois

Tools. The remaining equipment is simple. A medium size anvil, Fig. 38; two sledge hammers, medium and heavy; three, or perhaps four, forge hammers; tongs for holding round, flat, and irregular work; tools for cutting off material, both hot and cold; and finally flatting and swaging tools. Melting ladles can be placed over either coal or gas flame, and either forge can be used in melting the antifriction metals used in lining bearing boxes.

Blacksmithing Repair Outfit. A complete blacksmithing outfit that is adequate for ordinary repair shop work can be purchased for approximately $50. This will give a forge that uses coal as a fuel, a vise, a set of taps and dies, anvil, drill press, hammers, drills, tongs, wrenches, and a few small tools. Some of the tools that apply strictly to horseshoeing can be applied to the repair of automobiles. These consist of a farrier's hammer, knife, and pincers. All of the other tools mentioned apply to general metal work. A post drill will be found very practical for shops not provided with power. As complete sets of drills usually

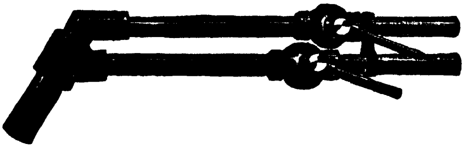


Fig. 37. Hand Gas Torch for Brazing

accompany the post drill outfit, it is not necessary to stock up on a variety of tongs, for these can be made best to suit the purpose for which they are to be used.

Electric or Gas Furnaces. If the shop is a large one, there probably will be considerable tool dressing that will require heat-treating of various parts, and an electric furnace may be procured to handle this class of work. With a furnace of this kind, the amount of heat may be regulated within close limits, and temperatures may be reached that are sufficiently high for hardening, carbonizing, or annealing any pieces within the range of the furnace. It is questionable whether a furnace of this kind would be practical, except for large shops where there is much of this class of work to be done. Furnaces of the gas- or oil-burning types, Fig. 39, are probably more serviceable and less expensive than the electrically heated form. Welding is a very useful repair process in automobile work and it will be found fully treated in another article.

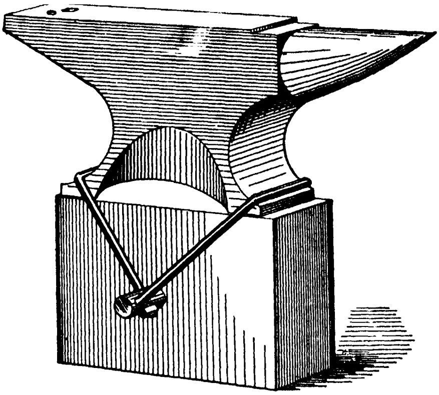


Fig. 38. Anvil Fastened to Block

Heat Treatment. Since there is an almost universal use of high-grade alloy steel in automobile construction, it is quite necessary that the repair man have some knowledge of heat treatment of the various metals. It must be known that metals of this character cannot be machined unless they are annealed and are of but little greater value than the ordinary machinery steel parts if they are not properly heat-treated to bring out the physical characteristics desired after fabrication.

Tempering Steel. The simplest method of tempering steel is the old-fashioned method of only partly cooling the tool when quenching it, then quickly withdrawing it, polishing off its working surface, and letting the heat which remains in the tool produce the required temper as judged by the color. When first quenched, the point of the tool is the coolest and, on withdrawing it, the heat in the balance of the tool heats up the point, changing its color from light straw to deep straw, then light brown, darker brown, light purple, dark purple, dark blue, light blue, and finally blue tinged with green and black. When the black color appears at the point of the tool, the temper has completely gone. When the color desired is reached, the tool should be completely quenched.

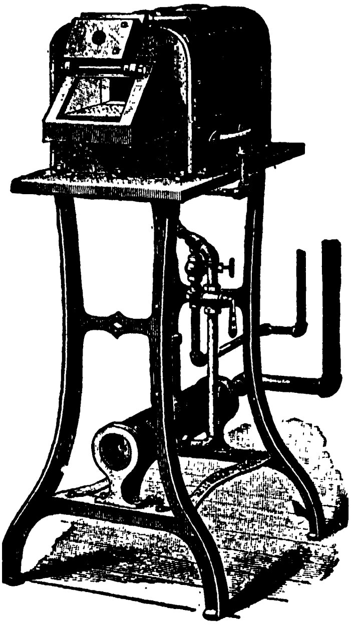


Fig. 39. Simple Gas Furnace
Courtesy of American Gas Furnace Company, New York City

The following tabulation shows the temperature in degrees Fahrenheit at which steel assumes certain colors.

Degrees	Color
430	Very light straw
450	Light straw
470	Dark straw
490	Very dark straw
500	Brownish yellow
520	Yellow tinged with purple
530	Light purple
550	Dark purple
570	Dark blue

The modern method of tempering is by means of a furnace, as shown in Fig. 40, an oil bath being heated by an oil or gas flame to the proper temperature, as indicated by the thermometer, and

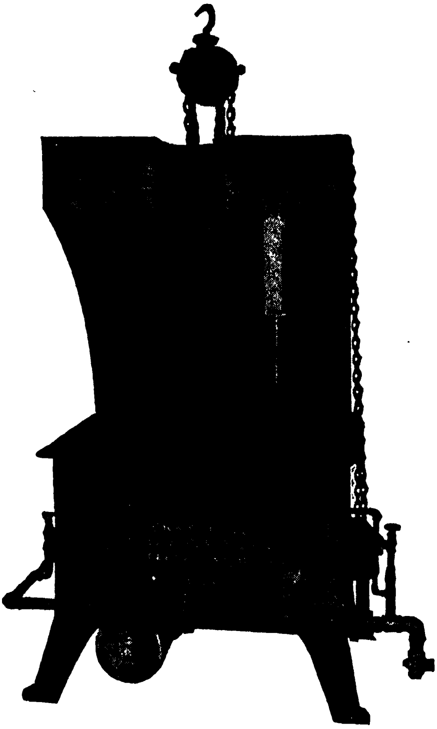


Fig. 40. Typical Tempering Furnace
Courtesy of Strong, Carlisle and Hammond Company, Cleveland, Ohio

the tools immersed in the bath. When they have reached the same temperature, they are lifted out and quenched in a hardening bath. The use of such a furnace makes the tempering of the shop tools more uniform.

Hardening Steel. As it is necessary to maintain the steel in the state it was at the moment quenching began, the quenching bath is a very important part of the process of hardening. The better the bath, the more nearly perfection is attained.

Various baths are used for cooling steel when hardening, on account of the different rates at which they cool the heated metal. An oil bath is used when the steel is wanted tougher and not excessively hard, as the oil cools the steel more slowly than water. Brine or an acid bath is used when the steel is wanted very hard, as they absorb heat more rapidly than water. For excessively hard work, mercury or quicksilver is sometimes used, as it absorbs the heat very rapidly.

Self-Hardening Steel. Self-hardening steel is used to a large extent in modern practice for lathe tools, much being used in the shape of small square steel blades held in special holders, as Fig. 41. Self-hardening steel, as its name indicates, is almost self-hardening by nature; generally, the only treatment that is required to harden the steel being to heat it red hot and allow it to cool. Sometimes the steel is cooled in an air blast or is dipped in oil. It is not necessary to draw the temper. The self-hardening quality of steel is given to it by the addition of chromium, molybdenum, tungsten, or one of that group of elements, in addition to the carbon which ordinary tool steel contains. High-speed steel is lower in carbon.

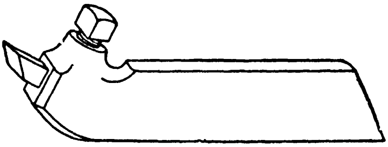


Fig. 41. Tool Using Self-Hardening Steel Blade

Self-hardening steel is comparatively expensive, costing from 40 cents and upward per pound, some of the more expensive grades costing $1 or so. However, when in use, self-hardening steel will stand a much higher cutting speed than the ordinary so-called carbon steel, and for this reason it is much more economical to use, although its first cost is higher.

Self-hardening steel cannot be cut with a cold chisel and must be either cut hot or nicked with an emery wheel and snapped off. Great care must be used in forging it, as the range of temperature through which it may be forged is comparatively slight, running from a good red heat to a yellow heat. Some grades of self-hardening steel may be annealed by heating the steel to a high heat in the center of a good fire and allowing the fire and the steel to cool off together. Steel which has been annealed in this way may be hardened by heating to the hardening heat and cooling in oil.

Hardening High-Speed Steel. High-speed steel has a much higher critical temperature than carbon steels. A temperature of about 1350° to 1600° F. is sufficient for carbon steels in general. High-speed steels require heating from 1800° to 2300° F. and to be cooled in oil such as machine, fish, or linseed.

Case Hardening. There are many parts in the automobile that are hardened but not in the sense that they are tempered or hardened throughout their entire length and thickness. Spring bolts, piston pins, ball races, cones, shafts and cams are case hardened. This consists of treating the steel with chemicals so that a very hard skin is formed on the surface of the part which in no way affects its strength but adds a considerable length of time that the part will remain in service. The thickness or depth of this hard skin depends on the length of time the steel is left in contact with the chemicals when it is hot.

A knowledge of case hardening will prove of use to the repair man for often a repair part can be made out of a good grade of mild steel and a hard wearing surface given by case hardening. There are two chemicals used in case hardening—cyanide of potassium and bone dust which consists of charred bone. The use of the two are very similar. The parts to be hardened can be treated individually or in large quantities. The method of hardening the individual parts is as follows: The part should be perfectly clean and free from grease. Heat in a forge or gas flame to a bright red color. Place the part in the chemical and allow it to remain for about five minutes so that the chemical has a chance to thoroughly soak into the steel. Remove and reheat and again put it into the chemical and repeat the process as often as desired. The more times the process is repeated, the deeper the hard skin. When the skin is deep enough, the part should be heated to a red heat, plunged into cold water, and whirled to be certain that it is cooled equally all over.

For quantity hardening, the parts are packed into a cast-iron box and bone dust will be found the most desirable chemical to use. A thick layer of the dust should be placed in the bottom of the box and a layer, of the parts to be hardened, placed in next and so on until the box is filled. A thick layer of the dust should be placed on top, the cover placed on the box, and the edges of the box filled in with clay. The parts should be arranged so that they will not touch each other. The box is placed in a furnace and heated to a cherry red. The length of time that it is kept at that heat depends upon the type of part being treated. Larger parts will have to be kept in the furnace longer than smaller parts. After the box and its contents have been heated to the desired temperature for the proper length of time, the box and contents are plunged into cold water. The parts are then removed and polished.

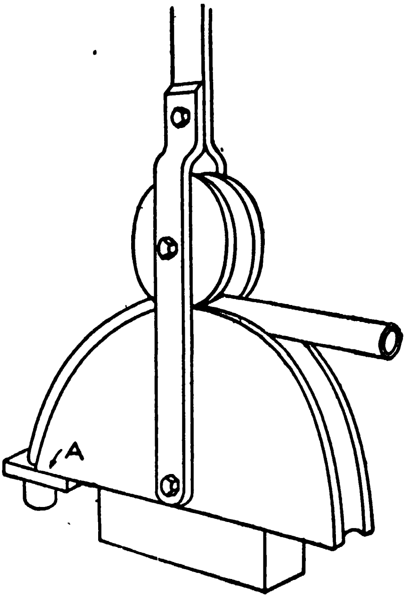


Fig. 42. Grooved Jig for Bending Pipe

Bending Tubing. If a piece of hard tubing is to be bent, it must first be annealed, otherwise it is likely to break. If the piece to be bent is thin-walled tubing, it will collapse. Occasionally, the bending of a moderately thick-walled piece of tubing can be accomplished without heating or filling, although it always is best to fill the tubing before attempting to bend it. If the interior is made solid, or nearly so, with some substance and if the tubing is properly heated and of the right temper, it can be bent to a curve of small radius without damaging the walls of the tubing. It is poor policy to avoid filling the tube by the use of a vise or wrench, or hammer and anvil for bending, as the walls of the tube will suffer and the appearance of the finished work will be unsatisfactory. There are several methods of filling tubing that give good results. Some molten substances can be poured into the tubing, such as resin for thin copper, and brass or lead alloy in steel tubing. The fillers can be removed by heating the tubing after the bend has been made. Some make use of a steel rod when the bending describes a part of a circle, as the filler rod takes the same curve as the tube and thus comes out easily. When many pieces of about the same size of tubing are to be bent, it can be very satisfactorily accomplished with a grooved jig, as shown in Fig. 42.

CUTTING GEARS

Definition of Terms. In designing or cutting gears, it is quite essential that the terms as applied to this practice be clear to the operator. The nomenclature of gears and their measurements are such that only by diagram, shown in Fig. 43, together with the following explanation, can one obtain a clear conception of the various measurements:

Pitch Diameter. The pitch diameter is the diameter of the *pitch circle.*

Addendum Circle. The addendum circle has the same diameter as the outside diameter taken over the points of the teeth.

Dedendum Circle. The dedendum circle is known also as the *root circle* and is the circle at the bottom of the teeth.

Pitch. Pitch is the distance from the center to the center of the teeth when measured on the pitch circle. Measured in this way, it is called the *circular pitch.*

Face. The face of the tooth is that part of the curve outside of the pitch circle.

Flank. The flank of the tooth is the portion of the curve within the pitch circle.

Thickness. The thickness is the width of the tooth, taken as the chord of an arc of the pitch circle.

Space. The space is the distance between adjacent teeth, measured as the chord of an arc of the pitch circle.

MISCELLANEOUS BENCH METHODS

Best methods for doing work are constantly coming up in all shop work, and the success with which the desired end is attained depends largely upon the skill and judgment of the man in charge.

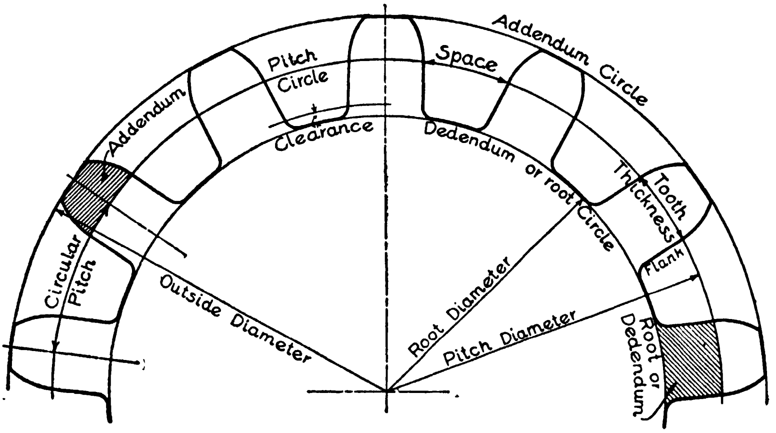


Fig. 43. Names of Tooth Parts

A few examples of the questions likely to arise and suggestions for handling them to give the best solution follow.

Peening. Stretching metal on one side of a piece of work is called peening. There is considerable difference between peening and bending. Let us suppose that you have a warped piece of metal to be straightened. If it were to be bent until it were straight, it could be placed on a block with the concave side down and struck with a hammer and driven down past the line of support. This strain would reduce it into an approximately straight line. However, this method could not be applied to a piece of metal with complicated outline for it would remain wavy. In peening to trueness such a piece as that previously mentioned, the piece is placed on an anvil with the convex side down and struck sharp blows with the peen of the hammer on the concave side, with the result that the metal is stretched at the point where the blow is struck. Working successively over the whole surface results in the concave side being stretched so that it is equal in dimension to the convex side, and the piece becomes straight and remains so. Skillful use of the hammer will straighten almost any piece of thin metal. The same process of stretching the metal is sometimes applied to a hole in a ductile metal which is too large. Possibly a screw has worked the threaded hole too large, but by peening the metal around the hole with a hammer and prick punch, the fit is made tight again. Such a method is not good shop practice but accomplishes a quick repair.

Drilling Hard Metals. When a hole is to be drilled in a very hard metal, the drill must also be very hard and must be run at a relatively low speed. The drill must be forced against the metal with as much pressure as possible without breaking the point and an abundant supply of oil is necessary. A drill may be excessively hardened by heating it to a dull red in a charcoal fire and quenching it in mercury instead of in water to make the cooling more rapid. Nicking the surface of the metal with a cold chisel also will give the drill a start, and beneficial results are obtained by using turpentine in place of oil in some cases. Very thin chilled cast iron may be softened somewhat by placing a small amount of sulphur on the place where the hole is desired and then heating to a dull red. This should be done slowly, however.

Avoiding Scale. When cast iron is being worked in a lathe or a planer, the point of the tool always should work beneath the scale, which is the outer shell that covers all cast iron as it comes from the foundry. This scale is very hard and brittle and if the edge of the tool is made to work in, or against it, the edge is soon dulled. When the tool works beneath the scale, raising the chip removes the scale.

Pickling. All castings that are to be machined to dimensions that are only slightly less than those of the rough castings should be pickled or washed in a solution of sulphuric acid and water, which causes the scale to drop off in flakes and leave the metal bare, unprotected, and rusty. Either submersion or swabbing is effective. After being pickled the casting should be washed in a sal soda solution. A good pickling solution for this work is one part of commercial sulphuric acid to ten parts of water.

MACHINES AND MACHINE PROCESSES

ARBOR PRESSES AND GEAR PULLERS

Types of Machines. An arbor press is one of the most useful tools for an automobile repair shop. Arbor presses are available in a number of forms. In the simplest type, the pressing medium is a rod which is forced down by pulling down on the handle which is counter-weighted on the opposite end. By a ratchet principle, the rod is held against the work while another stroke of the handle forces the rod farther down. When the handle is let up to the top of its stroke, the locking mechanism is released and the rod may be pushed up by hand.

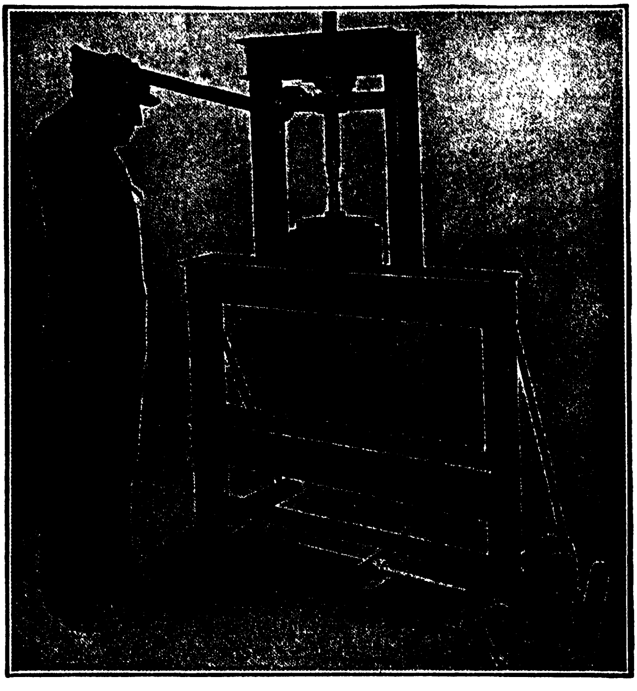


Fig. 44. Arbor Press for Automobile Work

There is now on the market a universal press especially adapted for automobile work, Fig. 44. This machine has a capacity of 22 tons and allows a 42-inch clearance for the work. It has two levers, one for high-speed work, geared 1000 to 1, and one for low-speed work, geared 2200 to 1. In the illustration, the mechanic is shown pressing off transmission gears with channel blocking, using the 2200 to 1 leverage. The other attachments furnished with the machine are shown on the floor.

Uses of Arbor Press. *V-Block.* For automobile work, a useful part of the arbor press equipment is a V-block, shown on the floor beside the machine in Fig. 44. This block is a receptacle for a great many different kinds of stock.

Handling Press Fits. In automobile construction, there are a great many parts which are a press fit into another part. A press fit differs from a sliding fit in that one piece must be forced into another for permanent location while those parts are performing their function; with a sliding fit, one part is located within another so that it may be readily moved, as in a bearing. The arbor press easily handles press fits in replacement and repair.

Where a shaft is a press fit within a gear, that shaft may be pressed into the gear by means of the arbor press. The gear should be located on the bed of the press. If it has a hub, the gear should be supported underneath as close to this hub as possible so there will be no danger of springing the gear. The shaft is then started into the hole; the screw or rod of the arbor press tightens down against it and presses the shaft into the gear. It is well to remember that the available pressure in an arbor press is enough to bend a sizable piece of steel, and with this in view, work should always be very carefully centered and, in the case of shafting, the shaft should be perfectly parallel with the sides of the hole it is about to enter.

Removing Bearing Bushings. One of the biggest fields for the arbor press in a garage is in the removal of bearing bushings. There are a great many places about the car where bearings are pressed into their containers, a notable instance being in the springs. Bearing bushings may be very readily pushed out of springs with an arbor press. In most universal joints the steel bushings are pressed in with an arbor press and about the only satisfactory way they can be removed is to press them out with the same kind of a machine.

Straightening Parts. Another use for the arbor press is in straightening parts. In the modern automobile, practically all parts which take a considerable amount of strain are constructed from alloy steel. In order to properly prepare alloy steel for severe strains, it must be heat-treated in an accurately calibrated oven to a temperature averaging about 1500° F. Too many repair men make the mistake of trying to straighten these heat-treated parts in a forge. Once they are heated in a forge, the value of the previous heat-treating is lost and it can only be put back into the metal again in a heat-treating oven.

Furthermore, parts made of alloy steel which have been subjected to the heat-treating process, although capable of tremendous bending strains, may nevertheless be bent without harm to them providing enough pressure is applied. An arbor press capable of exerting a 15-ton pressure can be used for straightening front axles, steering knuckles, and like parts.

The arbor press may also be used for straightening tubing and cylindrical parts, such as torsion tubes and rear-axle housings. In doing this work, a screw press is superior to the kind where leverage alone is the pressure factor, because it permits more careful pressing. With an available pressure of 15 or 20 tons, it is a very easy matter to crank a piece of tubing or a cylindrical part, such as a torsion tube or a rear-axle housing, and great care should be exerted in the bending operation.

Gear Pullers. Although the arbor press may be useful for gear pulling, there is a simpler device, known as a gear puller. Where gears are fitted to small shafts, they are in a great number of cases made a press fit on the shafting. If one were to attempt to hammer the gear off, he would very likely either damage the teeth of the gear or bend the shaft. A gear puller will remove the gear without damaging any part of the assembly. It is a simple device consisting of a beam at the ends of which two arms are fastened with pins, Fig. 45. These arms are constructed with hooks on the ends. Through the center of the beam is a thread cut for the purpose, and in this is a screw with one end shaped to a V and the other end squared to permit the application of a wrench.

In operating, the hooked ends of the two arms are fastened to the back of the gear or pulley. Then the screw is turned down until the V-end fits against the center of the shaft on the opposite side of the gear or pulley to which the hooks of the arms are fastened. Screwing down the screw by means of a wrench will exert sufficient pressure to force the shaft out of the gear.

Combination Gear and Wheel Puller. There is now an instrument on the market which is a combination gear and wheel puller, Fig. 46.

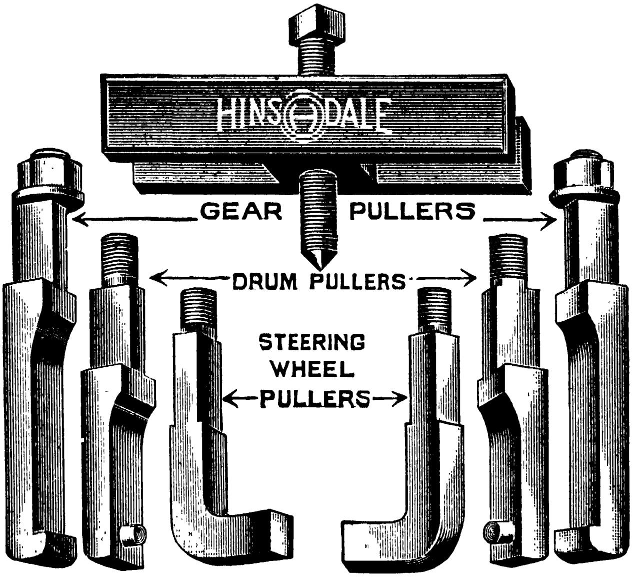


Fig. 45. Gear Puller
Courtesy of Hinsdale Manufacturing Company

As will be seen, in this instrument the arms cross like a pair of pliers, and the upper ends of the arms have a number of holes drilled in them. A center block between the arms carries the thread for the screw, as well as a tapped hole on each side. Screws are passed through the drilled holes in the arms at various points and into the tapped holes of the center block, thus giving considerable variation in adjustment for the different sizes of work.

GRINDERS

Advantages of Grinding. Machine-shop grinding operations depend upon the abrasive or cutting qualities of stone, emery, carborundum and corundum, when suitably held and presented to the work. The use of solid grinding wheels has made it possible to attain many refinements in machine construction that would have been impossible without them. It has made it practical economically to finish hardened steel parts that could not possibly be machined with cutting tools in the lathe or the planer, and with the softer materials it has made possible smoother and truer surfaces than can be obtained by any other method.

Types of Grinding. There are four principal divisions to grinding: hand grinding, tool and cutter grinding, cylindrical grinding, and surface grinding. The two latter classes are never required in repair work.

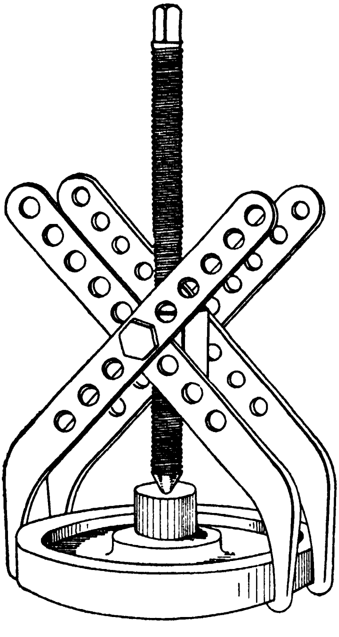


Fig. 46. Combination Gear and Wheel Puller
Premier Electric Company, Chicago

Hand Grinding. Under hand grinding is included all the operations in which the work is held to the wheel by hand or with a rest, as in rough grinding, ordinary lathe-tool grinding, buffing, and polishing. The class of machine used for this work is of the simplest form, consisting of the wheel-carrying spindle mounted on suitable bearings on a substantial head or pedestal. Some machines of this character carry one wheel, others two. Adjustable rests are provided upon which the work being ground can be steadied. This class of grinders is designed for dry grinding of rough and heavy material, where the danger of overheating the work is negligible.

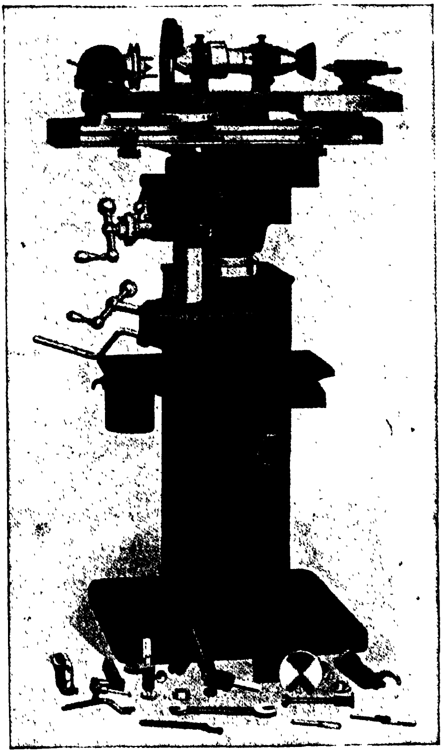


Fig. 47. Small Milling Machine Tool and Reamer Grinder
Courtesy of Cincinnati Milling Machine Company, Cincinnati, Ohio

If the work to be ground is tempered, or is likely to become over-heated, a grinder in which a supply of water is constantly on the rim of the wheel to keep the work cool is used. Buffing heads or spindles usually consist of a standard with a shaft carried on two bearings, the pulley for operating being mounted between the two bearings in a Y-yoke. This shaft usually extends well out from the bearings so that work may be conveniently handled. The ends of the shaft are fitted with wheels having rims of wood, leather, or cloth, which are charged with emery or other grinding material. With the buffer no rest is used.

Tool and Cutter Grinding. For tools and cutter grinding, a better class of grinding machinery is required than for the hand-grinding operations. In this case the term tool refers to drills, reamers, milling cutters, and the finest class of tools, and does not include ordinary hand or lathe tools, which usually are ground on a grinder where the wheel is in constant touch with water:

The Cincinnati Milling Machine Company makes a universal cutter and reamer grinder, shown in Fig. 47. As the name implies,

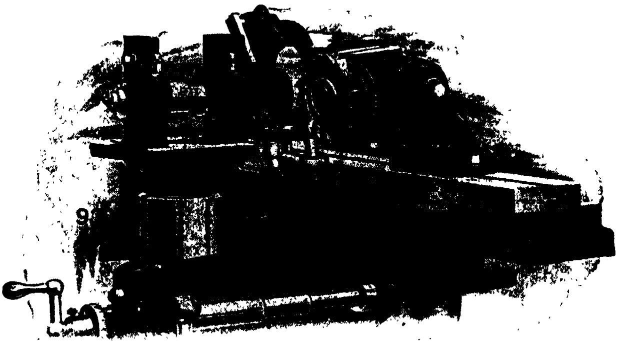


Fig. 48. Grinding Milling Cutter with Cup Wheel
Courtesy of Cincinnati Milling Machine Company, Cincinnati, Ohio

these tools are provided with all necessary attachments for grinding the cutting edges of all classes of reamers and milling cutters, and in many cases may be used for doing a limited amount of cylindrical grinding, both internal and external.

Cutter grinders have become very necessary to the modern repair shop through the extensive use of the rotating cutter in machining operations and the necessity of keeping these cutters true and sharp. In the grinding of cutters, care and judgment must be exercised, and not until the operator has become thoroughly familiar with all the setting combinations of the machine can he expect to get the best results. Since water is not used on the wheels of cutter grinders, the wheels are usually quite hard and fine, and light cuts must be made in order not to draw the temper of the tool at its cutting edge. The cutter support should be adjusted to bear against the tooth being sharpened, and its position relative to the wheel should be such as to give the necessary amount of clearance to the cutting edge. A setup of the above grinder for sharpening a milling cutter with a cup wheel is shown in Fig. 48. A grinding wheel of this type must not operate at a peripheral speed greater than 4000 feet per minute.

Care of Tools. *Twist Drills.* Although many shops are provided with a special machine for grinding twist drills, there are times when it is necessary to grind such tools by hand, and every workman should practice until he is able to do this properly without the use of a special machine. The cutting edge must make a proper and uniform angle with the longitudinal axis of the drill. They must be equal in length, and the lips of the drill sufficiently backed off for clearance; otherwise they will not cut easily, or if they do cut, they will make a hole larger than the size of the drill. Drills properly made have their cutting edges straight when ground to a proper angle, which is 59 degrees. It will be found that a correctly ground drill seldom breaks, since it cuts its way cleanly and does not scrape nor jam as it has a tendency to do when the angle and the clearance are not right.

Portable Grinding Machines. Portable grinding machines are becoming more popular in the repair shop for they can be used for many different jobs in which time saving is a big factor. The portable cylinder grinder is one of the most useful types. Fig. 49 shows the tool being lowered into position for regrinding the bore of a cylinder.

Fig. 50 shows another use for the grinding machine, that of dressing a piston to fit a cylinder. The tool is driven by an electric motor of small power and is economical in operation. The installation of this tool will save time in regrinding because the cylinder block will not have to be sent out and allows the repair man to keep the profit made on this class of work. The machine can be moved easily from one place to another in the repair shop and takes up very little space. It can also be set up to do surface grinding and attachments can be devised so that the tool can be used for valve refacing.

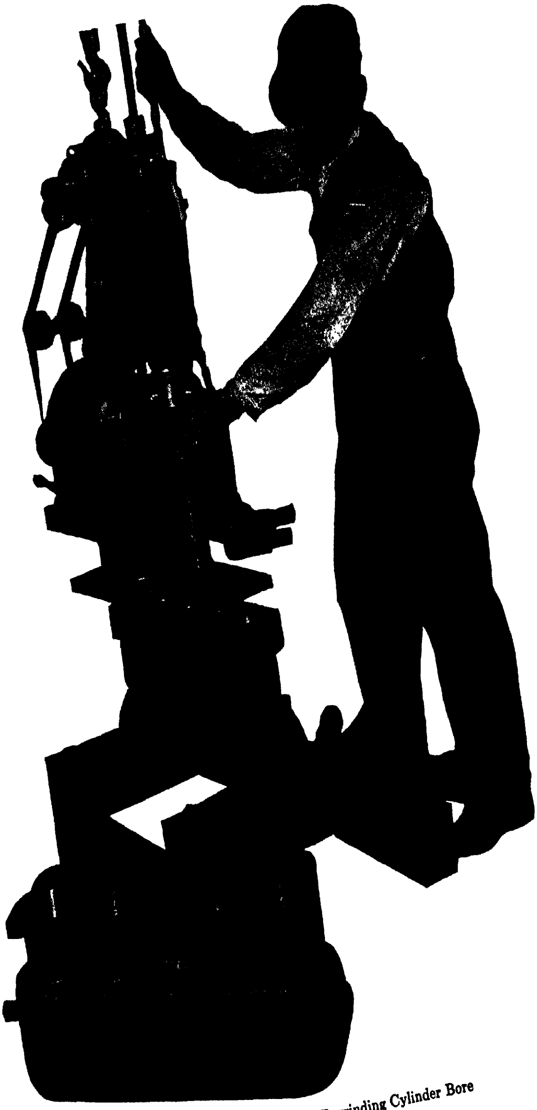


Fig. 49. Portable Grinder Regrinding Cylinder Bore
Courtesy of Gisholt Machine Company

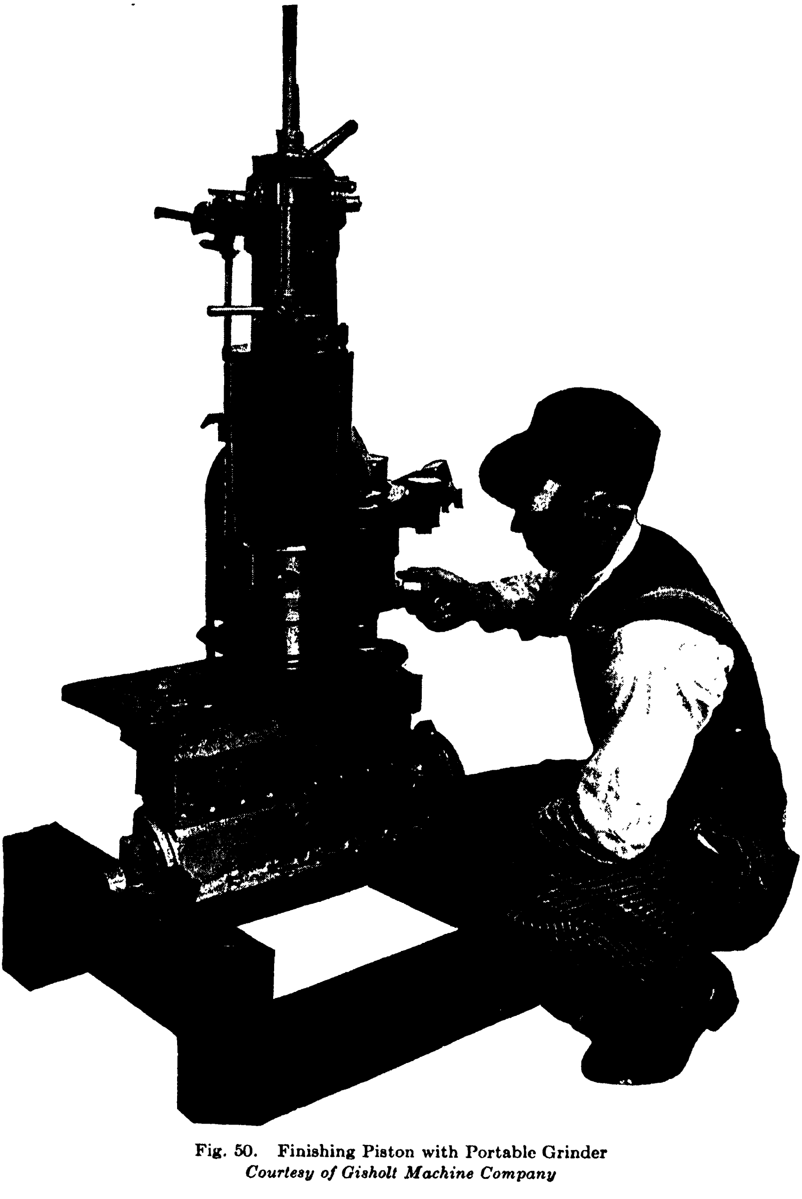


Fig. 50. Finishing Piston with Portable Grinder
Courtesy of Gisholt Machine Company

Proper Wheels. Wheels for any class of grinding should be properly adapted to the work as to shape, grade, and hardness. Shape and character of the work determine in any case the shape of the wheel to be used, while the material of which the work is composed, the amount of metal to be removed, and the condition of the finished surface must determine the quality of the wheel. A free cutting wheel which is run at the proper speed and with a light cut is best for accurate grinding, since it removes the metal without pressure and consequently cuts the high spots without heating up the work.

However, if the work is to be very accurate, it is best to use water on the wheel, as a slight temperature tends to have a noticeable effect upon the work. When long cuts are to be taken, it sometimes is difficult to get the wheel to stand up so as to give a parallel cut. Since the harder wheels hold the emery longer, they can be run somewhat slower and they are best adapted for giving cuts of this kind. The wheel should have a wide face and be of large diameter so as to present as many grains of abrasive as possible to perform the required work. It also is necessary to use the coarser feed and lighter cuts in order that the wheel may cover the entire surface before it drops materially in diameter.

Manufacturers of grinding wheels give a table of speeds for wheels of different diameter, but these speeds are not always best suited to the work. All wheels should fit easily, yet closely, on their spindle, to prevent any possibility of cracking, and a soft washer of uniform thickness should be placed between the sides of the wheel and the clamping washer. In grinding long work, it is quite necessary to support the work at one or more points between its end bearings, for otherwise true work is impossible.

DRILL PRESSES

Function of Drill Press. The standard drilling machine, in its various forms, consists primarily of a revolving spindle which carries the cutting tool; a work-holding plate, or table; and a substantial frame connecting the two. Details of spindle adjustment and also of spindle drives and feeds, while they differ in points of detail in the several designs and classes, all bear close mechanical relations to each other. Boring holes of comparatively small diameter is the specific field for this class of tools, but reaming and tapping these holes are in many cases added to the work of the drill by means of special tools and fixtures, thus taking over the work that at one time was done on the lathe.

Method of Action. In the class of drill presses termed standard upright, the feed is automatic, and usually a variety of feed speeds is given as well as an automatic knock-off that stops the work at any desired point. In addition to the automatic feed, both wheel and lever feeds are usually provided. The rack and pinion method of moving the spindle is common to practically all makes and types of drill presses. The spindle usually has its lower bearing in a quill which is given a close sliding fit in the head. The feed rack is secured to the quill. This has particular reference to that type of drill press having a sliding head, the head having a vertical adjustment on the front face of the column to adapt the machine to work of different heights and to drills and tools of varying lengths. The head is counter-weighted so as to make operation convenient. The head can be firmly clamped in any position.

An arm supports the work table and this arm is manipulated by means of a screw and a crank. It can be swung to a considerable angle either side of the spindle and firmly clamped in almost any position. In case the work is too high to be supported on the adjustable table, a lower-base table may be used.

A stationary head usually is found on the smaller machines of this class, all the vertical adjustment being accomplished by moving the table up or down, as required. Such machines are regularly made up to 52-inch capacity, the size indicating the maximum diameter of the work whose center can be reached by the spindle.

In work where small drills can be used, a light machine called a sensitive drill should be used in order to obtain the high speed required and the lightness of parts necessary. Here, the term sensitive commonly means lightness of parts, smooth running, and perfect balance, which enables the operator to judge as to the pressure he is applying to the drill and, consequently, lessens the danger of breaking the drill. Some manufacturers go a little farther and employ at some point in the drive an adjustable friction clutch with which the speed of the drill can be regulated.

Securing Work. Securing work on the table of drilling machines requires clamps, bolts, jacks, and blocking, as in other types of heavy machines. The same care should also be exercised in the setting, for true work requires careful setting. The use of a square and surface gage as well as good parallel bars is essential in setting up work for drilling. For through drilling, the work must be located so that the drill in passing through will enter a slot or the central hole on the table. If the work is too large or if for any other reason this cannot be done, then the parallel bars on the table should be used before putting on the work. These should be sufficiently thick to allow the drill to pass through without striking the table.

Lubrication in Drilling. Drilling of steel and wrought iron requires lubrication for the cutting tool, while cast iron and brass are drilled dry. Lard oil makes the most satisfactory lubricant, however, its cost usually makes its use prohibitive. The lubricant tends to conduct away the heat generated by the cutting tool and it should be applied directly on the part of the work that is being cut. Some drills have a special reservoir in the head for carrying oil and the lubricant is forced on to the cutting edge.

POWER HACK SAWS

Method of Action. Very general use is made of power-driven hack saws in the automobile repair shop. These machines use the regular pattern of hack-saw blades, which with proper care do a remarkable amount of cutting; the machines require but little attention and when properly adjusted will saw off work reasonably square. There is usually an arrangement by which the machine comes to a stop when the work has been cut and the saw drops through.

Pressure on the Blades. When the saw blade is new, the weight on the top of the saw frame should be a little less than after the teeth have become worn, for, when new, the saw bites into the metal considerably faster than after they have become dulled from use. Furthermore, there is danger of stripping the teeth or breaking the blade, especially if the work is of small diameter. A comparatively light pressure permits contact with but a few of the teeth at each point in the stroke. Tubing is very hard on blades and should be cut with a very light pressure and with saws which are somewhat worn. Never use oil on the hack-saw blade.

Pressure for Different Metals. It also should be borne in mind that different metals require different amounts of pressure on the saw. Unless one desires to break saws and strip teeth, a close adherence to the following must be observed: Aluminum or any other soft metal of this character cuts twice as easily as cast iron and approximately four times as easily and as fast as steel, consequently the weight on the frame of the saw must be moved forward or backward to give the proper pressure. Perhaps the best point for locating the weight in cutting aluminum is at the extreme outer end of the frame, about the middle for cast iron, and well toward the inner end for steel. Of course, there is no regulation of the backward and forward speed of the hack saw, hence it is necessary to bring judicious use of the weight into play if the life of the saw blade is to be preserved.

Power hack-saw blades should last as long in comparison to the amount of sawing done as the hand hack saw, perhaps longer, if the saw is not called upon to do duty at a faster pace than that for which it was designed.

Allowance for Cut. The novice in using the hack saw frequently does not make allowance for the cut but measures off the length of his piece, marking the exact length, and then starts sawing with the blade exactly on the mark. When the piece has been cut off, he finds that it falls short of his measurement, perhaps $\frac{1}{64}$ inch. This shows that allowance must be made for the width of the saw cut instead of sawing directly on the mark, for the $\frac{1}{64}$ inch which the blade removes sometimes makes the piece useless.

LATHES

Characteristics. Of course the most important power machine in a motor-car repair shop is the lathe. In this discussion, the engine lathe only will be considered in its simple form, or modifications of it, as shown in Fig. 51. The lathe is capable of handling a great variety of work. There are four main parts in the ordinary engine lathe: bed *A*, headstock *B*, tailstock *S*, and carriage *X*. The bed is the bench, or foundation, upon which the rest of the machine is supported. Placed on top of the bed are what are known as shears, which are really tracks upon which the moving parts ride. There are two pairs of these shears, and the headstock and tailstock rest upon the inside pair and the carriage on the outer pair. The headstock contains the pulleys and other devices which receive and transmit the power to the work. The tailstock is the holding device for centering

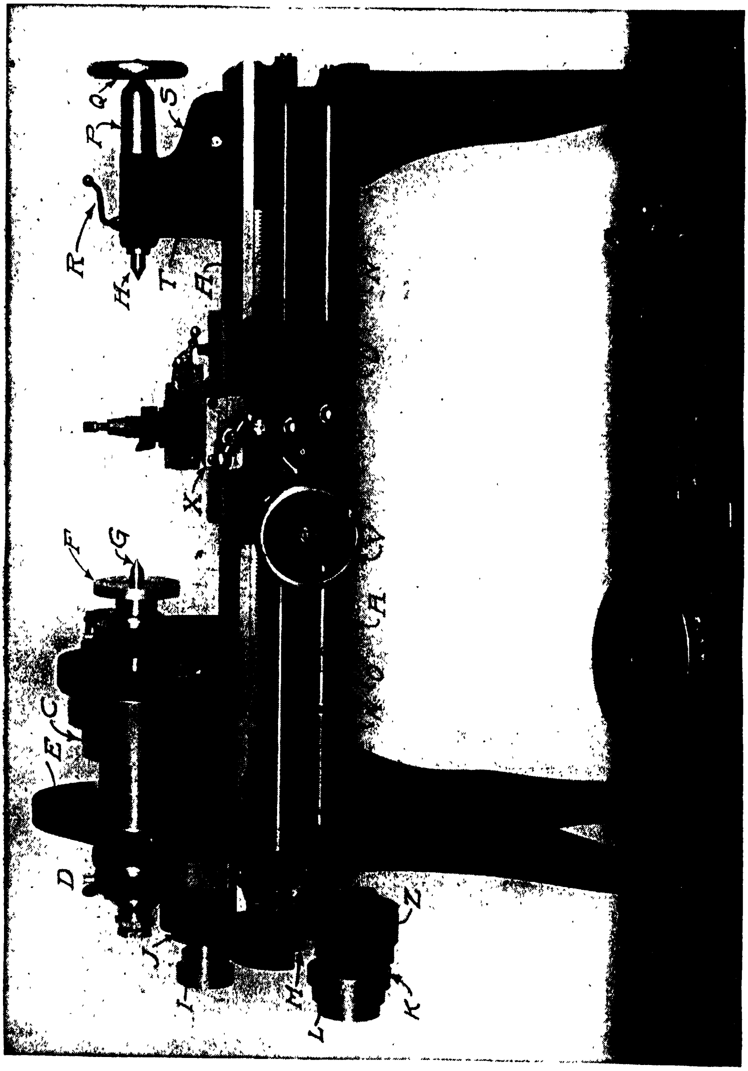


Fig. 51. Typical Engine Lathe
Courtesy of Reed-Prentice Company, Worcester, Massachusetts

material to be worked upon between itself and the headstock. The carriage carries the tools which perform work upon the material at hand.

Before attempting to operate a lathe, it is advisable for one to acquaint himself with the mechanism. An examination without instructions will show one what levers move the tail stock, adjust the tools, regulate the speeds, etc.

Lathe Tools. It is with the tools for the lathe that the amateur repair man finds his greatest difficulties. Only the most important points in tool use can be touched upon because of the limited scope of this article. Many shapes and sizes in cutting tools may be fitted for various jobs which one encounters but the standard tools will be found satisfactory for most jobs. Tool-holders for holding tungsten steel cutters are very useful and are probably more convenient than the usual lathe tools because the cutters do not have to be sharpened so often. In Fig. 52 are shown three typical forms of cutting tools. The first is a holder with straight body; the second, a cutting-off tool; and the third, a right-hand holder (left-hand holders are also available). There are a number of other necessary tools, of which thread-cutting tools and knurling tools might be mentioned.

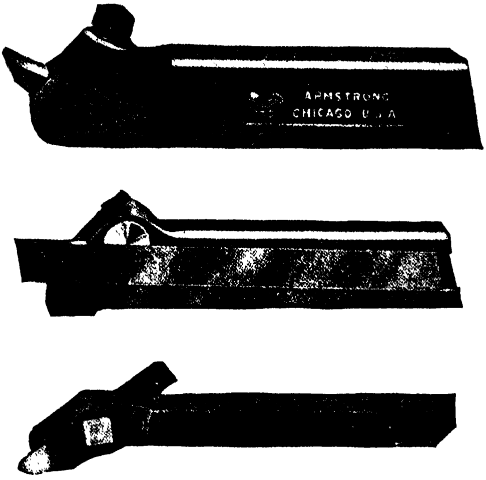


Fig. 52. Typical Lathe Tools
Courtesy of Armstrong Brothers Tool Company, Chicago

Lathe Equipment. *Headstock and Spindle.* The headstock is fastened on the left hand of the bed and carries the main running gear of the lathe. At each end of the headstock there is a bearing for the spindle. The right end of the spindle is threaded to carry the face plate *F*, Fig. 51, and is recessed to receive the live center *G*. The dead center *H* is mounted in the tailstock. The work is mounted between these centers, the left end of the work being held by a dog which is fastened to the face plate to keep the work from slipping.

Holding Devices. For lathe work in which only one end can be supported, there are four classes of holding devices: the center rest, the carriage, faceplate, and chuck. In center-rest work, the center rest of the lathe carries one end of the work and the live spindle the other. In carriage work, the work is secured stationary to the carriage and a rotary cutter mounted on the spindle performs the machining. With chucks or faceplates, the work is supported in jaws within a live spindle. A live spindle is one which rotates and is direct driven from the power medium.

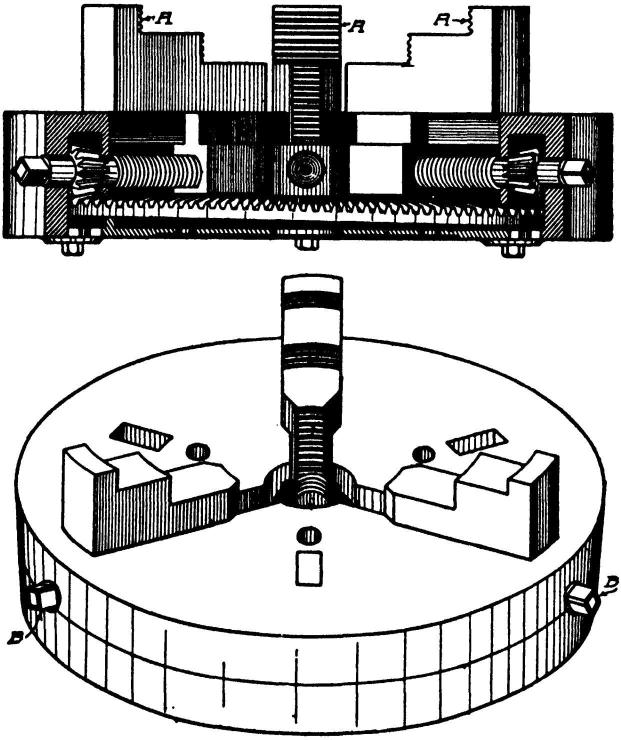


Fig. 53. Combination Chuck

Every lathe should have one or two chucks as a part of its equipment. These are made in two-, three-, and four-jaw types, but the three-jaw type, Fig. 53, is adaptable for most work.

Simple Lathe Work. The beginner's job on a lathe is to turn a plain spindle between centers. For example, assume that a bar of 1-inch round steel is to be reduced to a diameter of $\frac{7}{8}$ inch.

Centering Stock. The piece to be turned down is first cut to the proper length allowing enough for squaring and is then centered.

Centering means placing V-shaped depressions in the exact center of each end of the piece.

There are some very handy centering tools on the market which are adjustable for different lengths and diameters of stock and afford a quick means of placing an accurate center in each end of a bar. Fairly accurate centering can be done with a center punch and hammer. Each end of the piece must be bisected with two horizontal lines to obtain the center, this being done with a surface gage. Then depressions can be hammered into the ends of the stock by placing the point of the center punch at the point where the bisecting lines cross, which should be the center point of the stock. Another method is to mark the centers, as described, and drill centers into the end in the drill press.

These centers do not have to be deep or wide, but should have just enough of V to afford a firm support for the points of the centers. Where the work is going to consume considerable time and the piece which is being worked is heavy, it is advisable to make deeper centers and cut oil grooves into the sides of them with a cape chisel so that the center may be frequently oiled. In centering the piece, it must be neither a tight nor a loose fit.

Squaring Off Work. With the work centered, the ends of the piece are squared off with a cutting tool. This is an operation requiring care. The expert lathe man will square the end to within a very small fraction of an inch of the tailstock center, but will not ruin the center by cutting into it.

Roughing Cut. The next operation is the cutting down of the surface of the stock to within about $\frac{1}{32}$ inch of the finished diameter. The depth of each cut, of course, depends on the material which is being worked on. In soft metals, such as brass and aluminum, a fairly deep cut is possible, while in steel it should be around $\frac{1}{32}$ inch. This is a matter which can be determined by watching the action of the tool and examining the point frequently to see what effect the cuts are having on it. This roughing operation tends to work the center into a smooth easy-running bearing.

Reversing Work. The work is then removed from the centers and changed end for end. Another roughing cut is made and then the work is ready for the finish cut. It must be remembered that no part of the work shall receive its finish cut until the parts have been roughed over and the centers have been well worn in. These provisions are necessary for accuracy.

Finish Cut. The finish cuts must necessarily be light ones. On the second roughing, that is, the cut which is made after the piece has been reversed, the stock should be cut down enough, so that only one cut is necessary for the finish job.

Mild steel can be cut with cutting-speed settings of 25 to 100 feet per minute, depending on the hardness and quality of the stock. Although too much speed is to be avoided, it is a fact that the beginner generally cuts far too light, not realizing the possibilities in the cutting tool.

If the surface is to be a polished one, the mechanic must make some allowance for filing and finishing with emery. Here is found another beginner's fault in that he generally leaves far too much stock to be filed off. It must be remembered that it is a difficult proposition to file a rotating piece and still keep it cylindrically true. The finishing cut, when filing is to be done, should leave about .003 inch to be filed and smoothed off. This work of cutting down a bar between centers is the elemental training for all between-center work, in fact to a greater or less degree, for all kinds of lathe cutting.

Boring. The majority of work done in chucks and with carriage support comes under the head of boring. As work of this kind is usually performed on solid stock, it is necessary to drill a hole sufficiently large to allow the boring tool to enter. This hole can be easily drilled in the lathe by using an ordinary twist drill supported in the tail center. If the work is to be of large size, the taper shank drill is best suited for this work, inasmuch as it readily cleans itself of the cuttings. If the drilling is to be very deep, the drill must be frequently drawn out, cleaned, and oiled, or the generated heat will damage the flutes of the drill.

Drill and Boring Tool. The size of drill which one must use for making holes preparatory to boring depends, of course, on the nature of the work. If the work is to be small in diameter and of considerable depth, a drill within one-sixteenth of an inch of the diameter of the finished hole should be used if possible. If the hole is to be of large diameter and shallow, the drill should open a hole large enough to permit the entry of a short stiff boring tool, and this naturally does not have to be very large. There may be obtained boring bars of universal type which will take a variety of tool shapes. In these the tool is secured in a mortise through the bar by suitable wedges or, more usually, the tool is of round steel fitted into a hole through the bar and secured in position by a set screw. In cylinder boring, or reboring, more than one cutter is generally used inasmuch as a single cutter would be liable to spring the cylinder and gouge the metal. The use of a cutting bore equipped with three cutters gives a tool which will operate steadily and make a very satisfactory bore. As in all cases in lathe work, the finish cuts should always be light ones to insure true work.

Mounting the Work. It is more or less of an art to fit a piece, especially an irregular one, into a lathe chuck. No rules can be laid down for this inasmuch as each piece must be centered to take care of its regularity or irregularity in shape. In a good many jobs, the work is of such shape that it cannot be held in a chuck. In such cases, the work may be clamped to the face plate or to an angle plate fastened on to the face plate. This is a setup which requires a great deal of care and patience. In such parts as gear blanks and other pieces having hubs, the work should be chucked on these hubs whenever possible. Work held in this manner will run true if properly bored and turned. It must be remembered that a chuck centers the job. For instance, if one has a piece with a flange and a hub as a part of it, he can have the bore run true with the hub by chucking the work on the hub; but if he desires to have the bore run true with the flange, he should chuck the work on the flange.

Degrees of Fit between Shaft and Hole. When a piece of shafting or tubing is to be turned down to fit a certain drilled or bored hole, there are three kinds of fits which apply, viz, working fits; driving, or forced, fits; and shrink fits. A *working fit* is one such as is found in a bearing, that is, the work will be so machined that it will slide easily in the piece. A *driving, forced, or press, fit* is one in which the work is so machined as to require pressure, either by hammering or in an arbor press, in order to get the cylindrical stock into the hole. In automobile construction, a working fit is generally machined so accurately that the difference in diameter between the cylindrical piece and the hole is extremely small, and still a perfect sliding fit is maintained. The importance in fitting bearings is to have the surfaces of both pieces true to one another within .001 or .002 inch.

In accurate work, this agreement runs into ten-thousandths inch. A *shrink fit* differs very little from a driving fit. It must be so machined in both pieces that, when the bored or drilled piece is heated enough to expand it a few thousandths of an inch, it will allow the cylindrical piece to be easily pushed into it. Then when the heated piece shrinks or contracts, a very tight fit is naturally the result. There is one thing to be avoided in making a forced fit and that is the tendency to swage the metal. This is not the case in a shrink fit inasmuch as the piece goes in easily and then the hole closes squarely down upon the center. It is very important in making a press fit that the cylindrical piece be introduced squarely into the hole. In the shrink fit, it is quite necessary that the relative positions of the two parts, one within another, be quickly made because the shrinking takes place rapidly and causes the two parts to lock together. With a forced fit, in which it is contemplated that the parts will have to be separated, the surfaces of the hole and the cylindrical piece are lubricated, thus preventing oxidization of the metals and making it easier to drive out the shaft. The easiest way to do this is to heat the ring, thus expanding it, in the meantime keeping the shaft as cool as possible by pouring cold water over it.

SHAPERS

Characteristics. In many respects the shaper and the planer are alike. The same cutting tools may be used in either and the general principles involved in the operation of these machines are quite similar. However, they differ materially in design; with the planer the work moves to the tool, while with the shaper the tool moves over the work. On the planer the vertical and lateral feeds are given to the tool, while on the shaper the lateral feeds are usually given to the work and the vertical feed to the tool. In what is known as the traverse-head shaper, both feeds are given to the tool and the work is held perfectly stationary. A shaper of standard design is shown in Fig. 54.

Clamping Work in Shaper. Proper securing of the work in the vise on the shaper table for planing operations is a most important step in the production of satisfactory work. The variety of work assigned to the shaper is great and the operator will continually find himself with new problems to solve, problems that require the exercising of good judgment and care. In the majority of cases more skill is required in setting up the work than in the actual machining.

In work that is compact and heavy and where the amount of metal to be removed is comparatively small, there is but little danger of springing the work; but if the work is large, of irregular shape, or light, the danger of springing is materially increased. In the first place, lack of uniformity in clamping distorts the work and throws the machined surfaces out when it is unclamped. Again, the removal of the outer surfaces of a casting or forging, which frequently relieves shrinkage and forging strains, throws the work out of true. The first of these difficulties can be overcome only by using the utmost care in setting up the work, and the second, by first roughing off all surfaces as far as possible before taking any finishing cuts, thus allowing the work, after the roughing, to assume its normal condition.

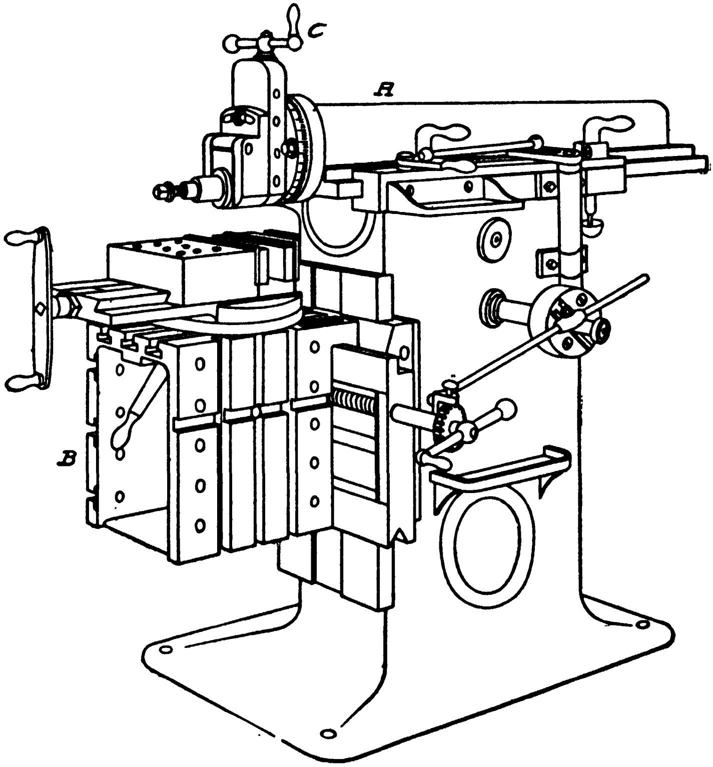


Fig. 54. Typical Pillar Shaper

It is very important that the clamping of the work to the table be done with due consideration for locating the points of clamp pressure directly over the points of support. The supports should be firm and bear about equally on the work and the table. If only a thin shim is required to level up the work, this should be of metal in preference to card board, leather, or any compressible material which will allow the clamp to spring the work. Good blocks and parallel bars are indispensable in the shaper and planer outfits. For work where the points of support vary in height, leveling wedges and small jack screws are excellent, as they can be adjusted quickly to any desired height. These wedges, especially if any single wedge is used, should have only a very slight taper.

Operation Suggestions. When it comes to operating the shaper, the beginner should keep a few points closely in mind. Not all geared shapers have a fixed length of stroke, the depth of the cut and the speed of the countershaft affecting in a certain degree the points at which reversal takes place. Some allowance must, therefore, be made for the overtravel of the tool. An excessive amount of overtravel, however, means a large loss of time. Roughing cuts should be as heavy and with as coarse feeds as the machine will conveniently handle and as the strength and character of the work will permit. First, before planing side surfaces, see that the top of the tool box is inclined from the work. This allows the tool to swing out and clear the work surface on the return stroke. If it is not inclined, the point of the tool drags hard on the work surface and, should it be inclined to the wrong side, the tool will swing into the work and do damage. Raising the tool clear of the work on the return stroke preserves the cutting edge. Means are often arranged for accomplishing this automatically.

Keep the cross-rail clamped firmly to the housing, when in use, and parallel with the table. Before putting in the feed, see that the feed gear is on the right spindle, as otherwise the tool may start up or down when it is intended to move across the work. As there is usually more than one way to do a certain piece of work, you should study which is the best way to do it. Those factors that have a great deal to do with turning out quality and quantity work are the manner in which the work is set up, the kind of tools and the way they are ground, as well as the efficient handling of the machine.

MISCELLANEOUS EQUIPMENT

Milling Machines. Although the milling machine is not an essential part of the well equipped repair shop, it is really a necessity in a large shop which does building and rebuilding and all kinds of machine work. In its elemental form the milling machine is made up of a rotating cutter which is held in one plane and a moving bed which carries the work under the cutting edges of this cutter. If one is to thoroughly familiarize himself with one of these machines, there is so much to learn in the setting and manipulation that it is hardly practical to try to give a detailed list of instruction herein. Therefore, only a brief description of the machine will be given. If a man has no idea of the operating principles of a milling machine, the quickest and best way to familiarize himself is to appeal for instruction from a man who knows how to operate this machine. The milling machine is a much more accurate tool than a shaper inasmuch as it cuts stock off with one sweep where a planer requires several sweeps with new adjustments for each sweep if accurate work is to be done.

Types. The plain and universal milling machine of the column pattern are the ones generally used for repair-shop work. In this machine, the upper portion of the column carries the spindle and cone, this spindle being back-geared in the same manner as is a lathe. The outer end of the spindle is supported by a suitable overhanging arm. The work table is adjustable vertically and horizontally, these adjustments being made by means of screws which operate with wheels and handles. There is a wide range of cutting speeds provided in the feed mechanism.

Cutters. Milling machine cutters are produced in a variety of forms designed to take care of different kinds of work. One of the most commonly used cutters is the axial type which has teeth on the cylindrical surface only. In the small cutters, these teeth are straight across the surface, and in cutters above 1½ inch they are cut spirally. Another and similar type of cutter is the plain milling cutter with nicked teeth. This has merit in being able to take a deeper cut inasmuch as the chips are broken up by the nicked cutting teeth.

The narrow cutters come in what are known as straddle-mill, radial-face, and side cutters. Another type is the end, or shank, milling cutter which is similar to the radial-mill except that it has its independent shank. These are generally used for small milling work, and frequently the teeth are cut spirally. When one desires to do slot milling at the end of a shank cutter, there is a special type provided, having radial teeth on the inner ends provided with cutting edges, which enables them to cut their way out when moved along the work. For cutting standard T-slots, there are special tools provided having a shank end and inasmuch as they work with the shank vertical to the slot, it is necessary that the center portion be cut away first to allow the narrow end of the shank to pass between. For annular cutting, there is a variety of tools built up to take care of every kind of this work. Probably the most economical for milling tools are those having removal cutters which may be replaced when worn out.

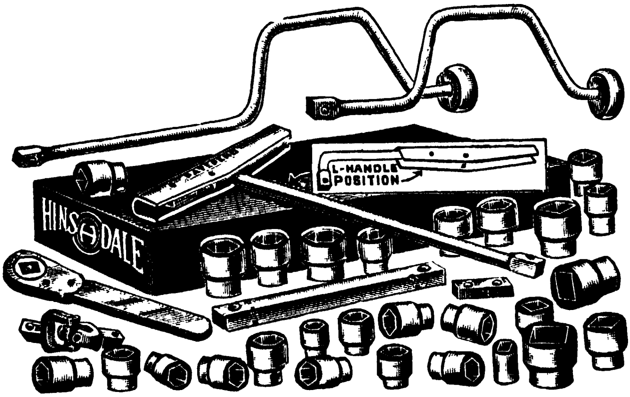


Fig. 55. Master Set of Socket Wrenches
Courtesy of Hinsdale Manufacturing Company

Planers. It is only in the very large repair shops that the planer will find use. As the name indicates, the planer is used for finishing flat surfaces and resembles the shaper.

Miscellaneous Tools. In addition to the machine and other tools there should always be a good assortment of tools and wrenches in the shop. There should be at least one set of open end wrenches, a large and small monkey wrench, a full set of speed wrenches in the form of a brace, and an excellent set of socket wrenches. The latter are one of the most useful tools in the repair shop because many nuts can be quickly and easily removed that could not be done with the ordinary straight or open-end wrench. Fig. 55 shows a master set of wrenches that will fit any nut that the repair man will come into contact with. Bending bars and twisting bars are essential if there is likely to be a great deal of straightening work to be done.

A portable electric drill is a useful addition to the repair shop equipment. Such a tool can be used for grinding valves, drilling holes, and for operating portable cylinder grinding equipment and cylinder hones. Cylinder hones are excellent for smoothing and trueing cylinder bores and give a fine wear resisting surface to the walls of the cylinder.

Engine and rear axle stands, on which the parts of the automobile are placed, are necessary if good work is to be done. There is not any mechanic that can do his work well unless he can stand upright in doing the work.

WELDING MANIFOLD TUBES IN AN AUTOMOBILE PLANT

Courtesy of Oxweld Acetylene Company, Chicago, Illinois

OXY-ACETYLENE WELDING PRACTICE

PART I

INTRODUCTION

Welding Field. The welding process is undoubtedly one of the greatest contributors to the efficient and economical manufacture of the modern automobile. It has made possible higher standards of body design and may be given almost exclusive credit for the light weight and great strength of the present-day motor car, producing stronger and better working parts through the use of pressed steel instead of the heavy castings for riveted parts, such as axle housings, Fig. 1, and manifolds, tanks, bodies, etc., Fig. 2.

In the field of automobile repair it is rapidly assuming an equally important place, affording a quick and inexpensive means of permanent repair to parts no longer obtainable from the supply house or manufacturer and permitting the building up of weak parts or the altering of the chassis, as may be required. This great adaptability of the welding unit has made it an essential part of the equipment of every efficiently managed repair shop.

WELDING PROCESSES

Old and New Methods. The old systems—blacksmith, or forge, welding, and brazing—are now seldom used in automobile work. In fact, most blacksmiths have equipped themselves to do welding in the modern way, using it almost exclusively for their repair work because it is cheaper, simpler, more efficient, and can be used on materials which could not be welded by means of the old-style methods. The modern systems of welding include the flame and electric processes. Because it is almost universally used in repair shops, the flame process and the apparatus required in its use will be discussed first. Several flame-welding processes have, from time to time, been introduced, all utilizing oxygen in combination with some fuel gas, such as acetylene, hydrogen, city gas, natural gas, liquid gas, Blau gas, carbo-hydrogen, thermaline, etc. Many enthu-

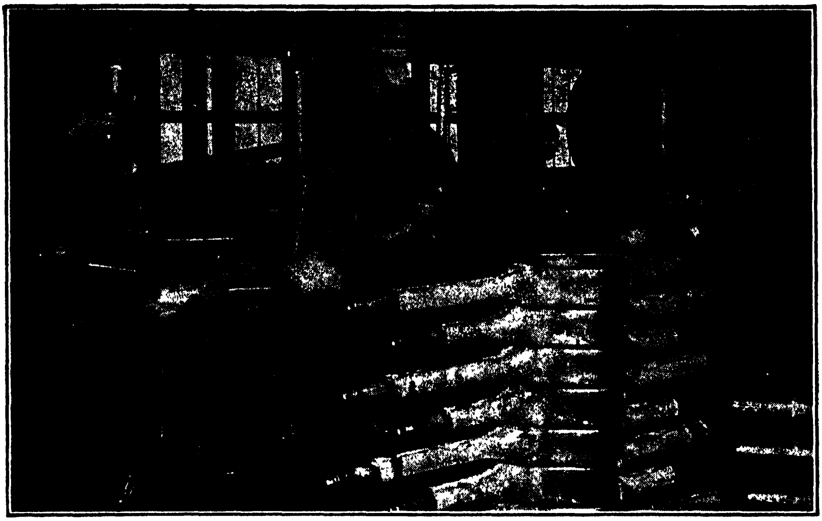


Fig. 1. Oxy-Acetylene Welding in Manufacture of Rear Axle Housings

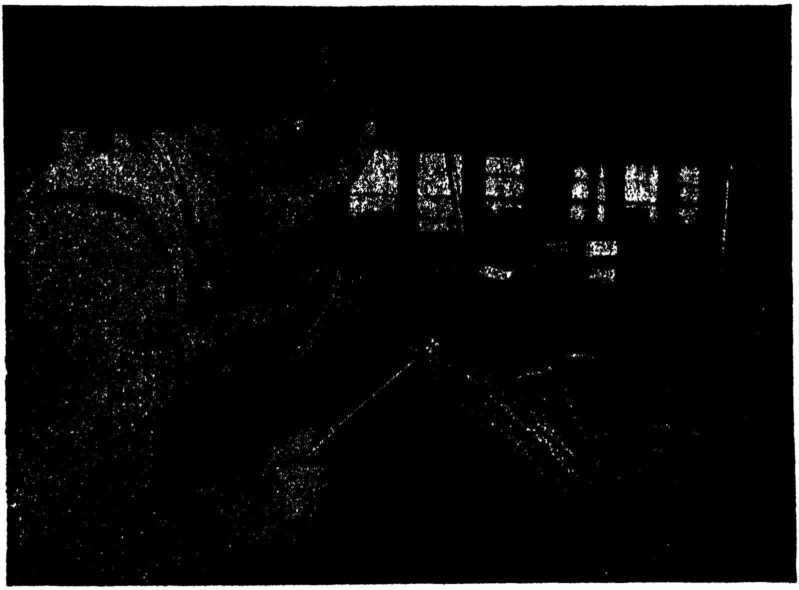


Fig. 2. Oxy-Acetylene Welding in Manufacture of Automobile Bodies

siastic claims of superiority have been made for each of these combinations by their advocates.

OXY-ACETYLENE PROCESS

Advantages. The easy control and intensity of the heat developed by the oxy-acetylene flame (approximately 6300° F.) and the adequate supplies of carbide and dissolved acetylene which are maintained in every industrial center in the United States have proved the greater desirability, economy, and efficiency of the oxy-acetylene process.

Another factor which has contributed largely to the popularity of the oxy-acetylene process is the comparatively inexpensive apparatus required and the low cost of its operation. Its speed, portability, and the ease with which its method of operation may be learned by any intelligent workman make it especially well fitted to the need of the automobile repair shop. Very seldom is any extensive dismantling of parts necessary in making an oxy-acetylene repair and, for this reason, it simplifies greatly the work of the repair man.

Gases. As is generally known, two gases are used in the oxy-acetylene process—oxygen and acetylene.

Oxygen. Oxygen is manufactured from air by liquefaction or from water by electrolysis. The former method is by far the greatest source of supply, furnishing practically all the oxygen used in this country and abroad. Oxygen made by the liquid-air process can contain only an impurity such as nitrogen, which cannot possibly do any harm. On the other hand, oxygen made by the electrolytic method contains some hydrogen, which will render it dangerous to handle if more than two per cent is present.

Because of the very high cost of an oxygen plant and the ease with which an adequate supply of compressed gas may be obtained from manufacturers' supply stations, it has been found impractical for even the largest consumers to attempt the manufacture of their own oxygen.

Almost everybody is familiar with the appearance of the oxygen cylinder, shown at the right in Fig. 3, which plays so important a part in present-day manufacturing. These steel cylinders contain 100 or 200 cubic feet of gas compressed to a pressure of 1800 pounds per square inch. They are furnished to the consumer without charge, the customer paying only for the oxygen and returning the cylinder to the manufacturer when the gas has been exhausted.

Acetylene. The acetylene may be obtained in cylinders, shown at the left in Fig. 3, containing 100 or 300 cubic feet, or, where large quantities are required, it is generated on the premises. Though frequently referred to as compressed, the acetylene in cylinders is really not compressed, but is dissolved in a solvent which has the property of absorbing many times its own volume of acetylene as pressure is applied. This liquid in which the gas is dissolved in no way affects the flow of gas except when the acetylene is drawn off from the cylinder at too rapid a rate. Experience has proved that when the gas is used at a rate greater than one-seventh the capacity of the cylinder per hour, the solvent is very likely to travel with the acetylene, lowering the temperature of the flame and thus hindering the work. To overcome this difficulty, where it is necessary to supply gas at a greater rate, several cylinders may be coupled to a manifold, or header, so that the total capacity is at least seven times their hourly discharge.

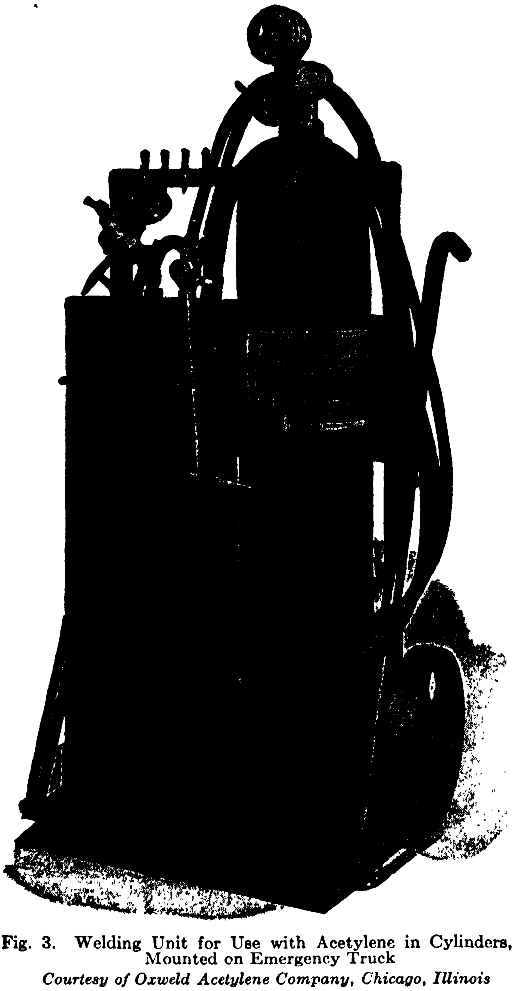


Fig. 3. Welding Unit for Use with Acetylene in Cylinders, Mounted on Emergency Truck
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Generators. By means of the acetylene generator it is possible to produce pure acetylene at less than half the cost of dissolved acetylene, so that if any considerable work is to be done a generator will pay for itself within a few months or a year. In these generators small quantities of calcium carbide are automatically fed into a large quantity of water, producing the gas at just the rate required by the work in hand.

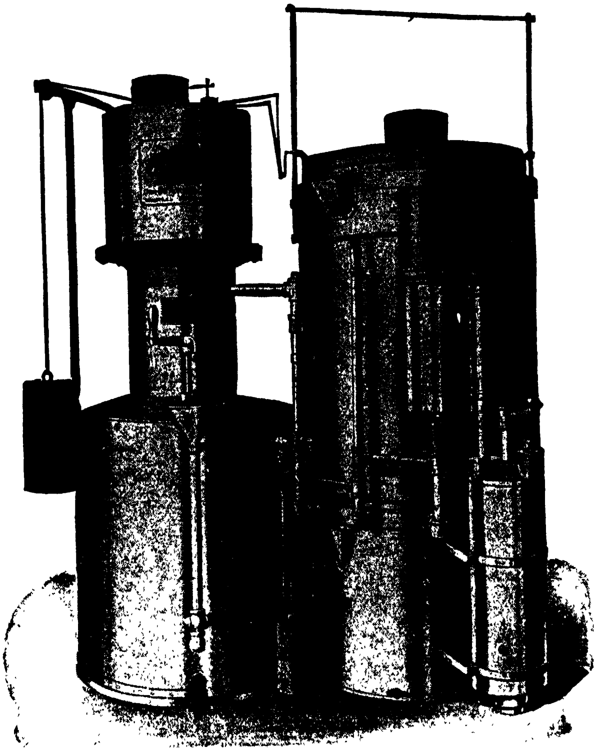


Fig. 4. Low-Pressure Acetylene Generator
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

There are two recognized systems of generating acetylene—the low-pressure system and the pressure system.

Low-Pressure Generator. This type of generator, Fig. 4, delivers acetylene to the blowpipe under a pressure of less than one pound. This system has the advantage of maintaining at all times an absolutely constant pressure, which is an essential requirement. The carbide feed is controlled by the rise and fall of the gas bell, in which the pressure is always the same, without the use of any pressure-regulating device.

Pressure Generator. The pressure generator, Fig. 5, delivers acetylene at a pressure of more than one pound. The carbide feed is controlled by the pressure in the generator. As the acetylene is drawn off and the pressure decreases, carbide is fed into the water; the generation of gas increases the pressure and the feeding stops. In order to compensate for this pressure variation, a pressure-diaphragm regulator, or reducer, is necessary so that the acetylene may be supplied to the blowpipe at a constant pressure.

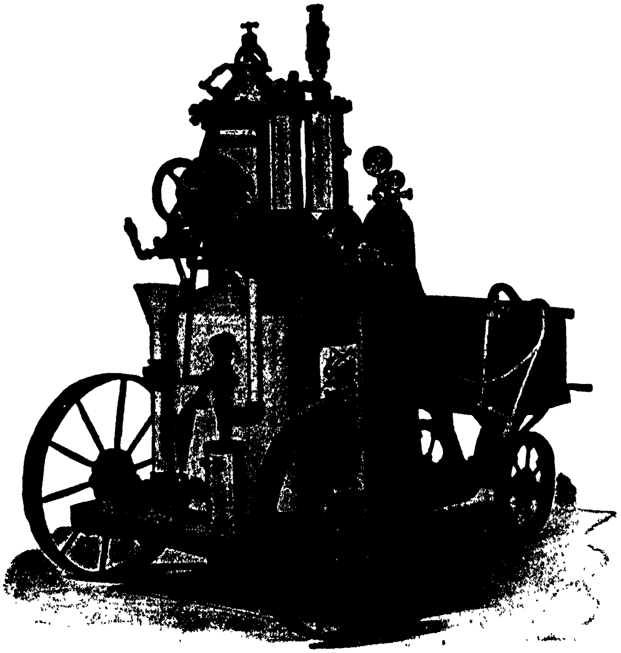


Fig. 5. Portable Pressure Acetylene Generator
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

The low-pressure generator furnishes the most satisfactory service under average conditions, though where portability is essential, pressure generators of compact construction may be obtained to meet this need.

Welding Blowpipes. There are two types of oxy-acetylene welding blowpipes, namely, the low-pressure, or injector type and the equal-pressure type.

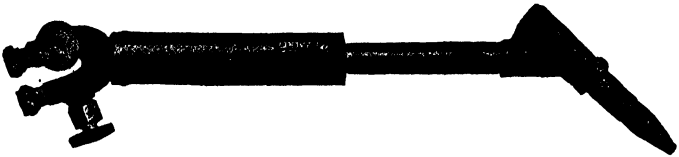


Fig. 6. Oxy-Acetylene Welding Blowpipe
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Injector Blowpipe. In the injector type, Fig. 6, the acetylene is delivered to the blowpipe at a pressure of only a few ounces. The oxygen at a higher pressure passes through the injector, Fig. 7, and expands rapidly into the mixing chamber. This rapid expansion and high velocity of the oxygen form a suction and draw in the acetylene at a constant ratio. A slight variation in pressure of either the oxygen or acetylene is automatically taken care of by the injector, so that a neutral flame is maintained at all times.

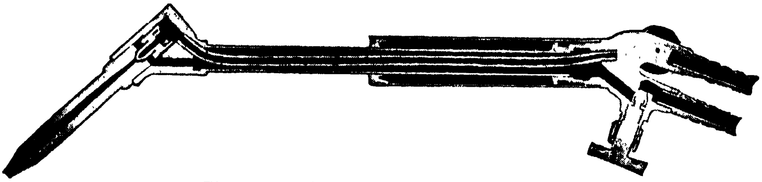


Fig. 7. Section of Injector-Type Blowpipe

Pressure Blowpipe. In this blowpipe the acetylene is used at almost the same pressure as the oxygen. The oxygen enters the mixing chamber at the rear and the acetylene through a couple of holes at the side.

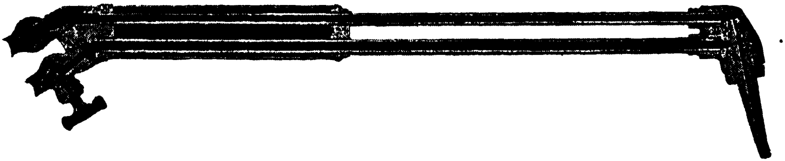


Fig. 8. Section of Pressure-Type Blowpipe

In the injector blowpipe the rapid expansion into the tapered mixing chamber sets up a whirling action and produces an intimate mixture of the oxygen and acetylene so that a ratio of 1.05 parts oxygen to 1.00 part acetylene is obtained, which is almost the theoretical or perfect ratio of 1.00 to 1.00. In the pressure blowpipe there is no means of obtaining such an intimate mixture of the gases in the mixing chamber, Fig. 8, which in most cases is not tapered, and consequently about the best ratio obtainable is 1.14 to 1.00. This larger amount of oxygen is, of course, wasted and, besides, tends to produce an oxidized weld. It is the surface oxidation, or burning, of the molten metal that leads some operators to believe that they are welding fast, while in reality they are only burning the surface and are not fusing the metal underneath.

Oxy-Acetylene Flame. The oxy-acetylene flame is the hottest flame obtainable. Its temperature of 6300° F. is 2000 degrees above that of any of the other flames. This high temperature allows the work to be done quickly and with only a very slight loss of heat due to conduction and radiation.

There are three phases of the oxy-acetylene flame, Fig. 18, namely, the neutral, or welding, flame; the carbonizing, or reducing, flame; and the oxidizing flame. Each of these has its characteristic appearance and it takes only a little practice to instantly recognize them. The appearance of these will be taken up later under "Flame Regulation", page 25.

Expansion and Contraction. These natural changes of the work, due to the heat of the welding, are taken care of in the case of rolled or forged materials by proper spacing of the edges or by holding the work in suitable jigs and, in the case of castings, by proper pre-heating and cooling. The most satisfactory methods of handling this feature will be taken up under the instructions for welding various materials.

Preparation of the Work. This is a very important feature and should receive the operator's best thought and effort. A fair amount of reasoning and planning on the part of the operator before he attempts a job will save considerable time and keep the cost of the welding low. The operator should figure out several ways and means of handling the particular task at hand, and should then select the best. This applies especially to castings, such as crankcases and cylinders, which may be welded perfectly if the operator uses good judgment but which will be ruined if he does not.

Welding Rod. Thin plates may be welded by bringing the edges into contact and fusing them together. For heavier work, the edges are beveled to form a groove, and a filling material, or "welding-rod", is fused into the groove. In most cases a material similar to the work being welded is used. The operator may build up the weld by means of the welding rod so that the section at the weld is greater than the section before welding, thus insuring a strength even greater than the rest of the piece.

Flux. A suitable flux is used in cast iron, aluminum, brass, copper, etc., welding to dissolve any impurities and to give a film, or protecting coating, to the fused material to prevent oxidation.

Both the welding rod and the flux used are extremely important factors in the welding and should be obtained from a reliable manufacturer who supplies only materials that are tested and analyzed to determine their purity and suitability for the work.

Strength of Weld. With proper equipment and suitable rods and fluxes, the strength of the weld will depend mainly upon the skill and care of the operator. An operator who has had considerable experience and who is careful with his work should be able to obtain as high as 95 per cent the strength of the original material, although 85 per cent may be taken as a safe lower limit for the average good welder.

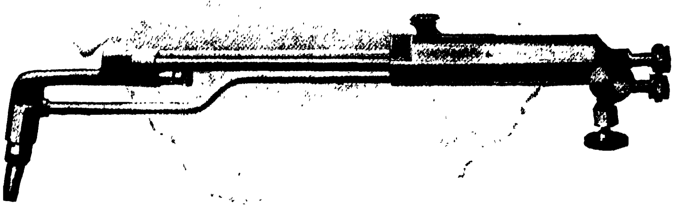


Fig. 9. Oxy-Acetylene Cutting Blowpipe
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Working and Hammering. If the weld is hammered when at the proper temperature, its strength will be increased, in the case of welds in steel, by making the grain of the material finer.

Experience of Operator. Poor work due to carelessness or inexperience of the operator, poorly designed and cheaply constructed apparatus that is not capable of handling the work, may be held responsible for such failures as may occur in the oxy-acetylene process.

The handling of the process is not difficult and, therefore, some operators undertake difficult jobs before they are sufficiently capable or experienced. When such a job fails, it is but natural that both the customer and the operator should blame the process rather than the way in which the work was handled. Time may be very profitably spent in practice on scrap material before undertaking work on materials with which the operator is unfamiliar. By thus laying the foundation for a satisfactory result, the operator may quickly develop his skill to the point which will bring him the confidence and patronage of a constantly increasing number of customers.

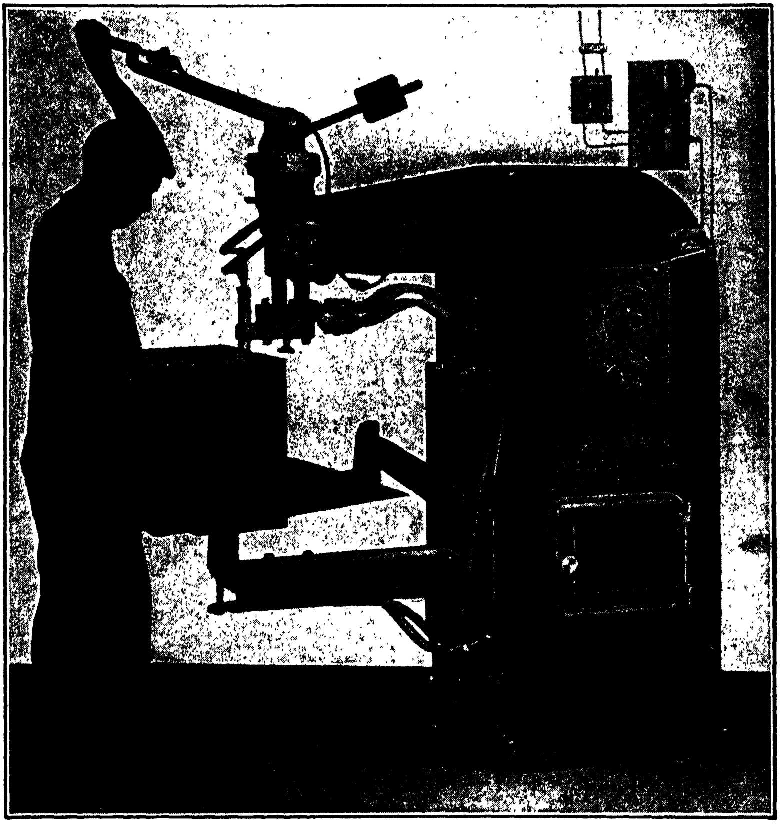


Fig. 10. Electric Spot-Welding Machine
Courtesy of Thomson Spot Welder Company, Cincinnati, Ohio

Oxy-Acetylene Cutting. Cutting by the oxy-acetylene process is done by means of a separate blowpipe, Fig. 9, quite different in construction from that used for welding. A more detailed description of the cutting process is given on page 79, Part III.

ELECTRIC PROCESSES

Methods. For a number of years electric welding was used as a laboratory experiment, but recently the process has been more fully developed. Two distinct methods are utilized: one, the electric-resistance welder, or spot-welder, Fig. 10; and the other, the electric-arc welding machine, Fig. 11.

Spot-Welder. The electric-resistance welding process provides for the passage of a heavy current through the joint between the pieces to be welded, allowing the resistance of the bad contact to heat them locally until they are soft enough to stick together; squeezing the pieces while soft will then cause them to adhere. This process is used mostly in making light automobile parts, such as mud guards, bonnets, etc., rather than for repair. It is also used to some extent instead of small rivets in light sheet-metal work and for spotting, or tacking, small parts together preparatory to welding them with the oxy-acetylene flame.

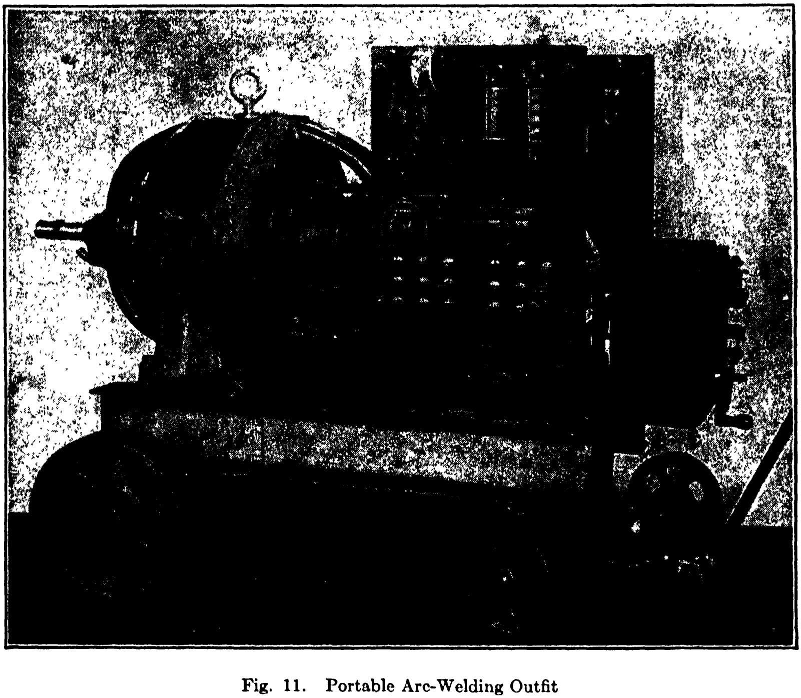


Fig. 11. Portable Arc-Welding Outfit
Courtesy of C & C Electric and Manufacturing Company, Garwood, New Jersey

Arc Welder. In order to do welding with the electric arc, after suitable equipment has been provided, it is necessary to first connect the work to the positive side of the power-supply circuit and the welding electrode to the negative side of the circuit by means of wires or cables, with the regulating devices in circuit to control the amouut of current flowing. The negative electrode is then placed lightly in contact with the work and quickly withdrawn to make the circuit and draw the arc, thus providing the high temperature required for welding.

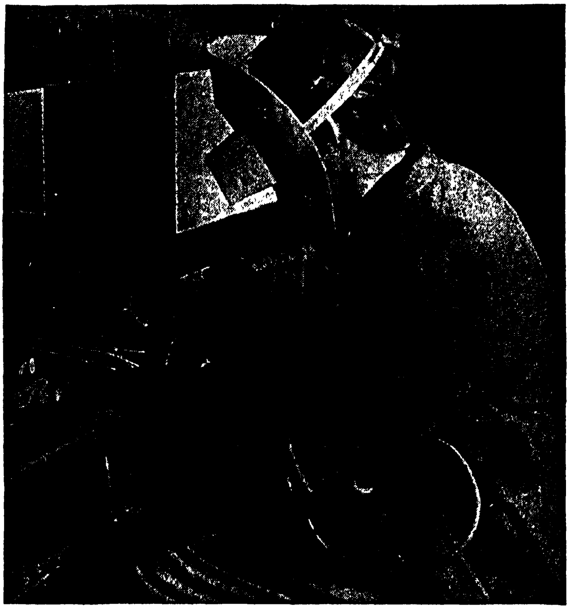


Fig. 12. Operator Using Metallic Electrode
Courtesy of C & C Electric and Manufacturing Company, Garwood, New Jersey

Electric-arc welding usually consists in using the heat of the arc to fuse, or melt, the filling material into the place to be filled, although the article worked upon may be melted down sufficiently to fill the space if it is large enough at the point to be welded.

Two methods, or processes, using the arc for welding, are in commercial use, these being the metallic and the graphite, or carbon, processes.

Metallic Electrode. The metallic welding process consists in using a piece of wire of the proper kind as the negative electrode of the arc and fusing it into place, drop by drop, Fig. 12.

Graphite Electrode. The graphite process consists in using a piece of graphite, or carbon, as the negative electrode and fusing a piece of metal into place by the heat of the arc.

Apparatus. It is possible, though not practical, to do electric-arc welding, having nothing but a source of primary current, and some means for regulating the amount of current flowing, but the use of resistance only as a means of regulating the amount of current flow is so wasteful that other apparatus must be used for the sake of economy. It is well known among electrical men that a motor-generator set gives the best regulation of voltage, therefore, the leading arc-welding outfits in use today consist of a motor-generator set with suitable rheostats, resistances, circuit-breakers, fuses, indicating instruments, and switches for controlling the motor-generator and welding circuits, Fig. 13.

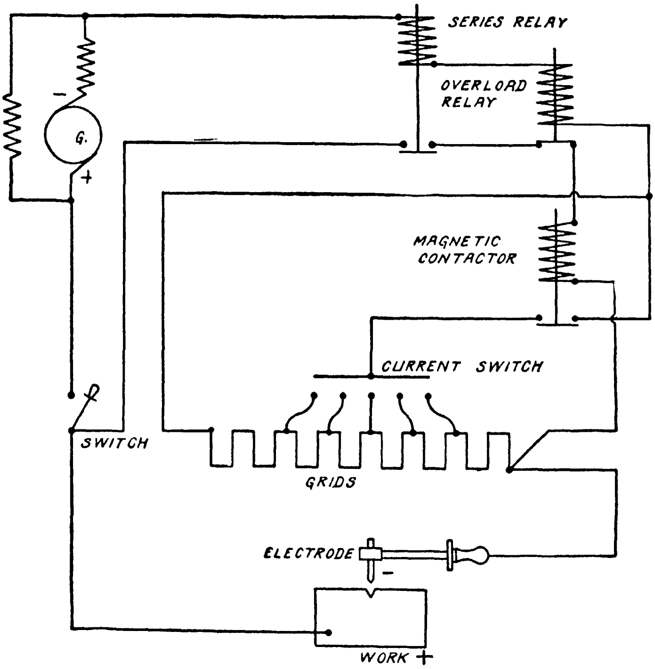


Fig. 13. Wiring Diagram for C & C Welding System

From the foregoing description, it will be surmised that an electric-arc welding equipment will be too expensive in initial cost for the average auto repair shop. However, it finds a useful field in the welding of very heavy work where there is sufficient volume of it to justify the investment.

TECHNIQUE OF OXY-ACETYLENE WELDING

SIMPLE WELDING JOB

Apparatus Required. The material in the following paragraphs must not be considered as instructions for welding but merely as a brief discussion of the various steps in making a simple weld. Complete instructions for connecting and operating the equipment are given in detail later. In general, the following equipment is needed for every welding job, no matter how small:

(a) A welding blowpipe
(b) A supply of oxygen
(c) An oxygen regulator
(d) A supply of acetylene
(e) An acetylene regulator
(f) Hose to connect blowpipe to oxygen and acetylene supplies

Preparing the Metal. First, the edges of the two pieces of metal to be welded are chamfered or beveled, so that when they are placed together the two beveled edges form a V, the width of the V being about equal to the thickness of the metal.

Next, the two pieces are placed together on a flat surface of fire brick, or other nonconductor of heat, so that the edges just touch at the bottom of the groove. This gives the line of the weld. The two pieces are then ready to be welded as soon as the apparatus is connected.

Connecting the Apparatus. To connect the apparatus, the following steps should be taken:

(1) The oxygen regulator is connected to the oxygen cylinder.
(2) The acetylene regulator is connected to the acetylene cylinder.
(3) The one hose is connected to the oxygen regulator and to the blowpipe.
(4) The other hose is connected to the acetylene regulator and to the blowpipe.

(5) A welding head is selected and attached to the blowpipe.

(6) The oxygen and acetylene are turned on and the blowpipe is lighted.

Welding. The operator is now ready to weld. He takes the lighted blowpipe in his right hand, Fig. 14, and plays the flame upon the beveled edges of the two pieces of metal to be welded. The intense heat of the flame melts the edges and they flow together. As the edges flow together, the operator melts in new metal from a rod which he holds in his left hand, so that the entire groove is filled up, producing a perfect union or weld.

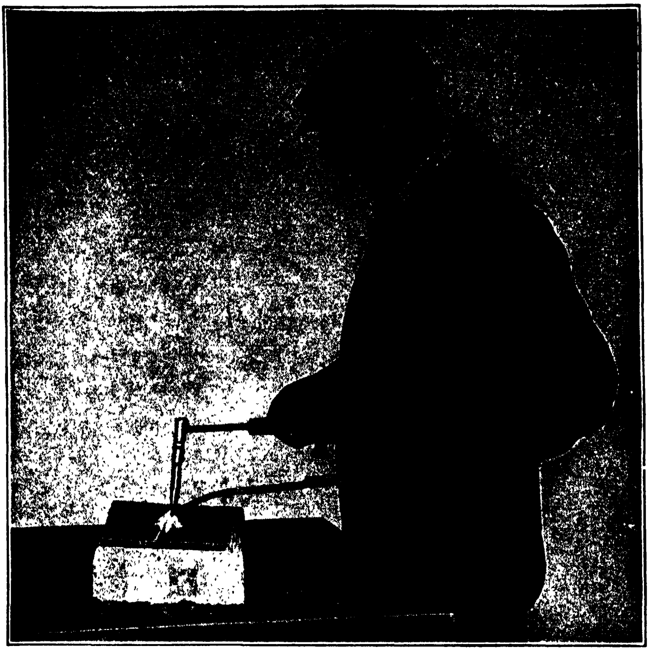


Fig. 14. Simple Job of Welding

When the entire groove has been filled in this manner, the operator turns out the blowpipe, and allows the metal to cool.

The foregoing is a brief outline of the steps taken by an operator in performing a simple operation of welding two small pieces of steel.

We will now take up these different steps and will give more specific and detailed descriptions of the welding apparatus and complete instructions in its operation and use.

OPERATION AND CARE OF WELDING APPARATUS

Necessity for Care. It is proper that in the operation of the welding apparatus we should lay stress upon the importance of careful and orderly methods in the handling of such apparatus. It should be borne in mind that the regulators and gages are sensitive measuring devices, that in the blowpipe the orifices are carefully designed and accurately machined to permit the passage of a definite quantity of gas and, therefore, that rough usage and abuse will certainly decrease their efficiency. It is not necessary in this place to give detailed instructions for the operation and care of the various makes of apparatus, because these are invariably furnished by the manufacturers with their equipment.

Because of the fact that dissolved acetylene is most generally used in garages and small job shops, we will confine our explanations to the use of apparatus with cylinder equipment. Owing to the greater simplicity of handling, however, the operator will have no difficulty in making use of generated acetylene when the opportunity arises.

Necessary Welding Apparatus. A complete welding station, Fig. 15, for use with acetylene dissolved in cylinders, consists of the following apparatus:

Welding blowpipe *G* with set of welding heads
Oxygen welding regulator *C* with two gages
Acetylene regulator *D* with one or two gages
Adapter *L* for acetylene cylinder
Two lengths high-pressure hose *E* and *F*
Darkened spectacles, wrenches, hose clamps, etc.

Welding Blowpipe. The two types of welding blowpipes were described on pages 7 and 8, and need no further explanation as to the principles of operation. They are furnished by the manufacturers in various lengths to take care of various classes of work, from short light-weight blowpipes less than a foot long for light sheet-metal work up to blowpipes several feet long, which allow the operator to stay away from the intense heat as far as possible when working on heavy jobs.

Welding Heads and Tips. About ten sizes of welding heads, or tips, are supplied for use on different thicknesses of metal and various classes of work, each giving its own special size flame. The oxygen consumption of the various size heads ranges from about 4 to 70 cubic feet per hour. In some makes the heads are made of one piece, while in others they consist of a brass or bronze body and a copper tip, which can be easily and cheaply replaced when necessary.

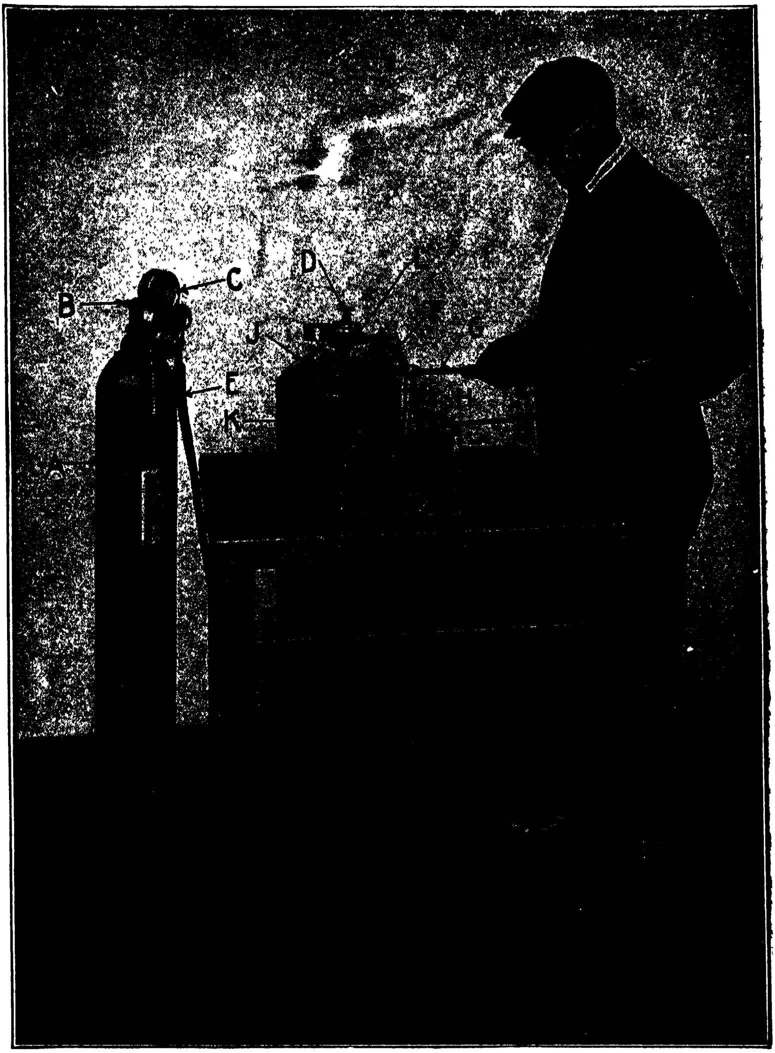


Fig. 15. Complete Welding Station

Working Pressures. The necessary pressures of the gas that are required by the different size welding heads are given by the manufacturers, and it is very important that the operator use only the pressures recommended if he wishes to get the best economy and the strongest weld possible. Some operators believe that by increasing the pressure above that specified by the maker of the apparatus that they are able to do the work more quickly and easily. This idea is wrong, because when the pressure is increased, the larger volumes of oxygen and acetylene cannot mix as well, so that oxide forms in the weld and has to be removed. This takes more time and is very likely to leave a slightly oxidized and weak weld.

If the welding head being used is not large enough, use a larger size; never try to increase the ability of the smaller head by increasing the pressure.

Fig. 16. Cleaning Blowpipe by Means of Oxygen under Pressure

It is equally bad to use a pressure that is too low. If this is done, continual back-firing will result.

Care of Blowpipe. If the blowpipe is handled properly there will be very little deterioration. It should only be necessary to clean the replaceable and working parts and occasionally ream out the tips.

The tips should never be reamed out with any instrument other than a copper or brass wire having a long taper. Care should be taken that the orifices of the tips are not enlarged by reaming. If they become enlarged, they may be closed slightly by placing a conical swag over the end and tapping lightly with a hammer. The end of the tip should then be dressed off square by means of an extra fine file, and the orifice trued round by reaming with a twist drill of the proper size.

The blowpipe may be cleaned by removing both the acetylene and the oxygen hose and connecting the tip to the oxygen hose. Fig. 16, and turning on the oxygen to a pressure of about 20 pounds per square inch, having the *acetylene* needle valve *open* and the oxygen needle valve closed, so as to drive any obstructions through the larger acetylene passages of the blowpipe. Then close the acetylene valve and open the oxygen valve to clean out the oxygen passages.

Regulators. There are various types of regulators on the market today, but the most successful ones are very similar in design and construction. The principal parts of a constant-pressure regulator, Fig. 17, consist of the body proper, regulator valve, diaphragm, pressure-adjusting spring, safety-relief valve, and gages.

The diaphragm may be either special reinforced rubber sheeting or phosphor bronze. The former is preferred, because it is less likely to crack, or split, is more readily replaced, and gives more sensitive regulation because of its finer elastic properties.

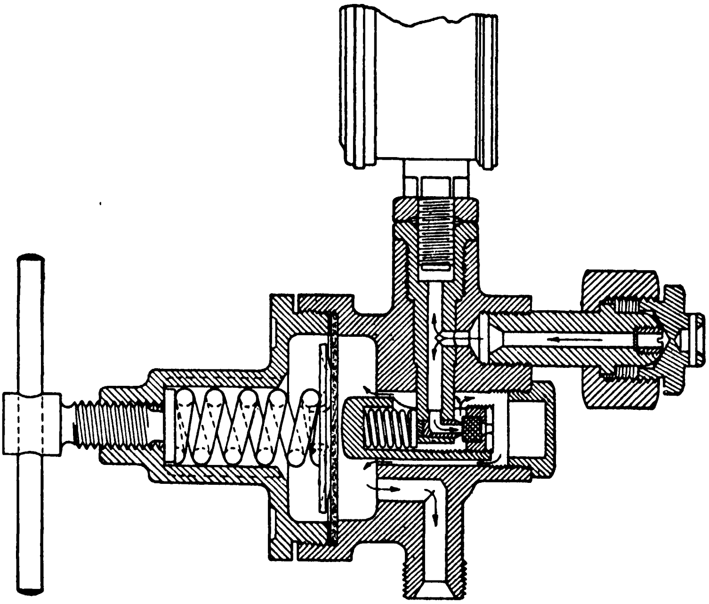


Fig. 17. Section of Pressure Regulator
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Operation of the Regulator. Gas passes from the cylinder valve through the passageway to the regulator valve. The pressure overcomes the tension of the inner spring and moves the sleeve-piece toward the back of the regulator, opening the valve. This allows gas to pass into the diaphragm chamber and out of the regulator by way of the hose connection. As the pressure in the diaphragm chamber increases, the tension of the pressure-adjusting spring is overcome, the diaphragm deflects, the sleeve-piece moves forward, and the valve closes partly or all the way. Then, as gas passes out of the regulator and the pressure in the diaphragm chamber decreases, the tension of the pressure-adjusting spring and the pressure of the gas entering the regulator move the sleeve-piece backward, admitting more oxygen to the regulator. The pressure in the diaphragm chamber builds up as before, the diaphragm deflects, the sleeve-piece moves outward, and the valve closes.

Oxygen Welding Regulator. This is an automatic regulator which is especially designed for welding operations. It is connected to the oxygen cylinder and is designed to deliver oxygen to the blowpipe at any uniform pressure at which the regulator is set. To do successful welding, the oxygen regulator must be as nearly perfect as it is possible to construct it. This device is required to reduce a pressure which may be as high as 1800 pounds per square inch in the cylinder and which is constantly varying, down to a pressure from 10 to 30 pounds per square inch; at the same time the regulator must keep the lower pressure constant.

Oxygen regulators are usually equipped with two gages. The high-pressure gage shows the pressure of the gas in the cylinder and may be used to determine the amount of oxygen (see under Measuring Oxygen, page 101, Part III). The low-pressure gage shows the operating pressure at which the oxygen is being supplied to the blowpipe.

Acetylene Regulator. The acetylene regulator is used with acetylene supplied in cylinders. It is connected to the acetylene cylinder adapter, and this to the acetylene cylinder. The acetylene regulator is designed to deliver acetylene at a uniform pressure, as needed by the blowpipe.

Acetylene regulators are usually equipped with a large gage that shows the pressure in the cylinder, but which cannot be used to accurately determine the contents (see Measuring Acetylene, page 104, Part III). A small gage is not necessary with the low-pressure, or injector, blowpipe, because the acetylene pressure required by this type of blowpipe is very low—only a few ounces. With the pressure blowpipe, however, a small gage is necessary, because it is important to know that the acetylene pressure, which ranges from 2 to 13 pounds per square inch, is supplied to the blowpipe at the required pressure for the tip used.

Care of Regulators. Never drop or jar a regulator. Do not use oil, grease, or any organic material for lubrication in connection with regulator. If it becomes necessary to lubricate the pressure-adjusting screw, or to repack a needle valve, make use of a little glycerine—nothing else.

Do not allow dust to enter the regulator. Always insert the dust plug when the regulator is not in use. These are supplied with most regulators and are intended to keep dust out of the regulator when it is not in use and to protect the union nipple at the back.

Do not change the regulator from one cylinder to another without releasing the pressure-adjusting screw. The diaphragm is liable to be ruptured if there is tension on it when the sudden rush of gas takes place as the cylinder valve is opened.

Do not attempt to repair, adjust, or change the internal mechanism of the regulator, other than replacing the diaphragm and resurfacing or replacing the valve seat. Send it to the manufacturer for repairs.

Do not replace diaphragms or valve seats with any material other than that supplied by the manufacturer for this purpose.

Hose. The best hose that it is possible to obtain should be used, because it is really the most economical in the end, although it might cost more at the beginning. A good grade of two-ply hose will be found to be flexible, light weight, easy to handle, and, at the same time, will not kink easily nor be permanently flattened if heavy objects happen to accidentally fall on it. In selecting a hose, the welder should see that he gets a hose that has a finished inside surface, so that small particles of rubber and dust will not flake off and be blown into and clog the blowpipe or welding head.

It is best to use different colored hose for the oxygen than for the acetylene to prevent errors in connecting and to avoid any possible danger from interchanging.

Care of Hose. Both the acetylene and the oxygen hose should be blown out occasionally so that dirt and dust will not be carried into the blowpipe. This can be done by removing the hose from the blowpipe, connecting each in turn to the oxygen regulator, and allowing oxygen of about 20 pounds per square inch to blow through it. Examine the hose, from time to time, for leaks by immersing in water when under pressure.

INSTRUCTIONS FOR CONNECTING APPARATUS

Preliminary Operations. The following directions are given as a starting point for beginners in the operation of welding equipment. The letters given refer to the labeled parts in Fig. 15, page 17.

1. First open the oxygen cylinder valve *B* for a moment to blow out any dirt or dust which may have collected in the valve, so that it cannot enter the oxygen regulator when it is attached to the cylinder.

2. Remove the regulator dust plug and attach the oxygen regulator *C* to the oxygen cylinder *A*.

3. Connect the oxygen hose *E* to the oxygen regulator and to the oxygen hose connection on the blowpipe *G*. The hose connections are usually readily distinguished by markings on the needle valves.

4. Release the pressure-adjusting screw on the oxygen regulator by turning to the *left* until it is perfectly free.

Do not open the valve on the oxygen cylinder until positive that the adjusting screw on the regulator is fully released. The diaphragm may be ruptured and the regulator put out of commission.

5. Slowly open the oxygen cylinder valve *B as far as it will go. Not part way.*

Do not leave the valve on the oxygen cylinder only part way open. This valve seats when fully opened or closed, but is likely to leak when open only part way.

Do not handle the regulator with greasy hands nor allow any oil, soap, or organic matter to come in contact with any part of the regulator or cylinder valve. Oxygen under high pressure coming in contact with these substances is dangerous.

6. Wipe out the acetylene cylinder valve to remove any dirt or dust which may have collected in the valve, so that it cannot enter the acetylene regulator when it is attached to the cylinder.

7. Attach the adapter *L* to the acetylene cylinder *K*.

8. Remove the regulator dust plug and attach the acetylene regulator *D* to the adapter.

9. Connect the acetylene hose *F* to the acetylene regulator and to the acetylene hose connection on the blowpipe *G*.

10. Release the pressure-adjusting screw on the acetylene regulator by turning to the left until it is perfectly free.

11. Open the acetylene cylinder valve about three full turns by means of the wrench *J*.

12. Select the welding head of the size suitable for the work in hand. Screw the welding head down firmly, but not too tightly, into the head of the blowpipe with the wrench provided for that purpose.

Starting the Work

How to Light the Blowpipe. 1. Take the blowpipe in hand and open the oxygen needle valve fully.

2. Turn the oxygen pressure-adjusting screw to the right until the required pressure for the welding head being used shows on the low-pressure gage. See the maker's chart for the correct pressure.

3. Close the oxygen needle valve.

4. Open the acetylene needle valve fully.

5. Turn the acetylene pressure-adjusting screw to the right until a good jet of acetylene issues from the welding-head orifice. In the case of pressure blowpipes, turn the screw until the required pressure for the welding head being used shows on the low-pressure gage. (See the maker's chart for the correct pressures).

6. Open the oxygen needle valve slightly and light the blowpipe by means of the pyro-lighter that is usually furnished.

7. Open the oxygen needle valve fully.

NOTE: A back-fire might occur when turning on the oxygen if there is not enough acetylene being supplied. If this occurs, increase the acetylene supply by turning the acetylene pressure-adjusting screw farther to the right.

8. Adjust the acetylene pressure-adjusting screw to give a slight excess of acetylene to the flame.

9. Adjust the acetylene needle valve to give a neutral flame (see under Flame Regulation, page 25).

How to Shut Off the Blowpipe. In the case of the *injector type blowpipe,* first close the *acetylene* needle valve, and then the oxygen needle valve.

In the case of pressure blowpipes, first close the oxygen needle valve, and then the acetylene needle valve.

When laying aside the blowpipe for a short time, the pressure-adjusting screws on both regulators should be released by turning to the left until free.

When work is suspended for any considerable time, the valves on both cylinders should be closed.

Never light the blowpipe unless some oxygen is passing through it. If the blowpipe is lighted, or burned, with only acetylene passing through it, there will be a deposit of carbon made in the tip, which will in time clog the orifice and interfere with the perfect operation of the blowpipe.

Back-Firing. If the flame is not properly adjusted, or the tip becomes clogged, the blowpipe may back-fire. When this occurs, first close the acetylene needle valve quickly, then open it again fully and relight the blowpipe. If the back-fire continues, close both the acetylene and oxygen needle valves. Then relight the blowpipe and proceed in the usual manner.

If the blowpipe becomes overheated, it may back-fire. When this occurs, it may be cooled by plunging it into a bucket of water. Be sure that the acetylene has been shut off and a small quantity of oxygen is flowing through the blowpipe to prevent water backing into the tip and causing further back-firing when the blowpipe is relighted.

Oxy-Acetylene Blowpipe Flame

Character of Flame. The oxy-acetylene flame consists of two parts—an inner cone, which is incandescent; and an outer envelope, or nonluminous flame, which is sometimes called the secondary flame.

The temperature of the oxy-acetylene flame, taken at the extremity of the inner cone, is very much higher than that of all other flames. It is calculated to be approximately 6300° F. One of the main reasons for the superiority of the oxy-acetylene flame over all other welding lies in the fact that this high temperature is concentrated at the point of inner cone.

The character of the oxy-acetylene flame depends upon the proportion of oxygen and acetylene contained in the mixture and the thoroughness of the mixture as it issues from the tip of the blowpipe. Varying proportions of the gases produce three characteristic types of flame, Fig. 18, called, respectively, reducing, or carbonizing, flame; neutral, or welding, flame; and oxidizing flame. Each type has its characteristic appearance, and it takes only a little practice to instantly recognize each. The welder should at all times observe carefully the type of flame produced and promptly correct any divergence.

Neutral, or Welding, Flame. A neutral flame is produced when acetylene and oxygen burn in the proper proportion, theoretically 1.00 volume of oxygen to 1.00 volume of acetylene. The appearance of this flame is characteristic, Fig. 18 b. It is made up of a distinct and clearly defined incandescent cone, or jet, of bluish hue, surrounded by a faint secondary flame, or envelope, purplish yellow in color and of a bushy appearance.

The incandescent cone may be from $\frac{1}{16}$ to $\frac{3}{4}$ inch in length and is usually rounded or tapered at the end. The maximum temperature of the oxy-acetylene flame is $\frac{1}{16}$ to $\frac{3}{16}$ inch beyond the extremity of this cone.

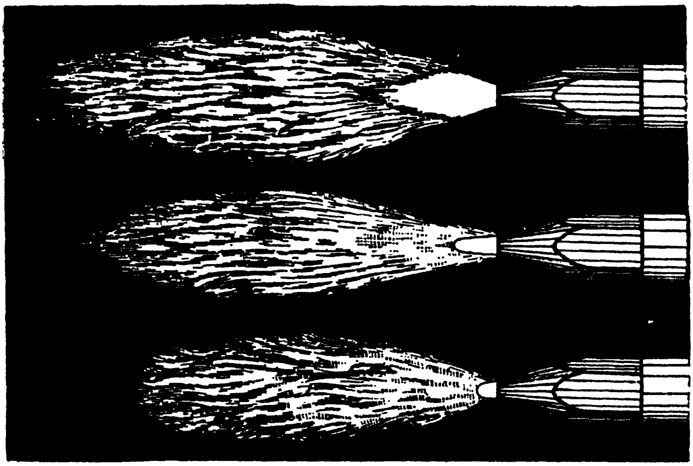


Fig. 18. Oxy-Acetylene Flame. Top, Reducing Flame; Middle, Neutral Flame; Bottom, Oxidizing Flame

The middle illustration in Fig. 18 shows roughly the characteristic appearance and formation of the neutral, or welding, flame. This flame is the one most extensively used, and no welder is proficient until he is thoroughly familiar with its appearance and distinguishing characteristics and is able to maintain this flame under working conditions.

Flame Regulation. The neutral flame is obtained by starting with a flame having a slight excess of acetylene and gradually cutting down the acetylene supply by means of the blowpipe needle valve. As this is done, the streaky appearance of the inner cone will gradually diminish. The flame is neutral when the streakiness just disappears.

Carbonizing, or Reducing, Flame. The reducing, or carbonizing, flame is produced when there is an excess of acetylene in the flame. This flame is of an abnormal volume, dirty yellow in color, of uniform consistency, and has a streaky appearance. By gradually decreasing the acetylene supply at the needle valve, the size of the flame is decreased, and gradually a white cone of great luminosity appears at the blowpipe tip. The extent of the reducing, or carbonizing, action of the flame is judged practically by the size and definition of the luminous cone. When this cone becomes more clearly defined and takes the form and color of a bluish white incandescent cone, or pencil, the streakiness is further diminished, and the flame approaches the neutral stage. The upper illustration in Fig. 18 shows a reducing, or carbonizing, flame that has a fair but not large excess of acetylene. The temperature of the reducing flame is considerably lower than that of the neutral flame.

Use of Reducing Flame. A slight excess of acetylene is used in the welding of brasses, bronzes, aluminum, and certain alloy steels to guard against the burning out of easily oxidized elements. It has also been used in the case of certain mild steels to increase the carbon content to secure greater hardness. In this connection it must be remembered that increase in hardness is usually accompanied by decrease in strength, so that in general welding an excess of acetylene should not be used.

Oxidizing Flame. An oxidizing flame is produced when there is an excess of oxygen in the flame. The effect of too much oxygen is to diminish the size of the flame, blunt or blurr the inner cone, and produce a weak, streaky, or scattering flame. In some blowpipes, the inner cone is not only diminished in size but is slightly bulged at its extremity as compared with the neutral flame, which is shown in the middle of Fig. 18. The lower illustration in Fig. 18 shows the oxidizing flame.

Caution Against Oxidizing Flame. An oxidizing flame should be carefully guarded against or it will become a source of trouble. An excess of oxygen will burn the metal, causing weak welds, and in the case of cast iron it will produce a hard weld that will be difficult to machine.

Manipulation of Blowpipe and Welding Rod

Position of Hose. Occasionally the hose is thrown over the operator's shoulder. In this case the weight of the blowpipe is suspended and held by the hose so that it is only necessary to impart the peculiar welding motion to the blowpipe, which can usually be done by the fingers. However, this method is not generally recommended, as it seriously hinders the free movement of the welding flame. It should be used only as a relief when the work is of long duration and the operator's wrist and forearm become tired.

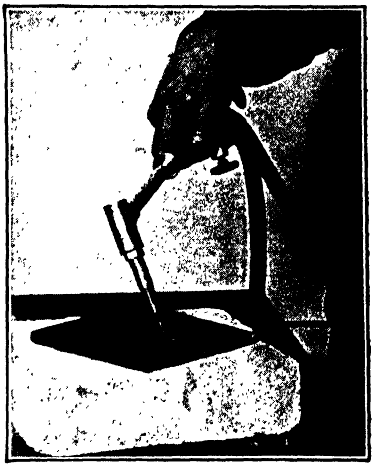


Fig. 19. Correct Method of Holding Welding Blowpipe

Position of Blowpipe. The operator, having lighted the blowpipe and properly adjusted the flame, is now ready to begin welding. Grasp the blowpipe firmly in the hand, as shown in Fig. 19. The blowpipe is so designed that it balances properly when grasped at this point. It is not good practice to hold the blowpipe in the fingers, because it is not possible to manipulate the flame with as great regularity and control, nor will it be possible to do as heavy work without tiring.

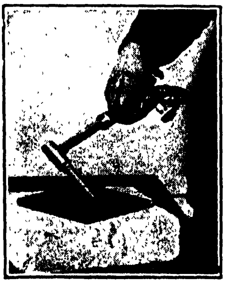


Fig. 20. Blowpipe Should Not Be Inclined Too Much

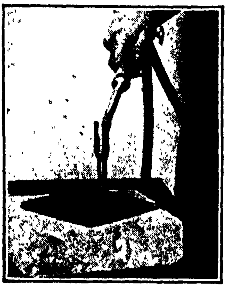


Fig. 21. Blowpipe Should Not Be Held Too Vertical

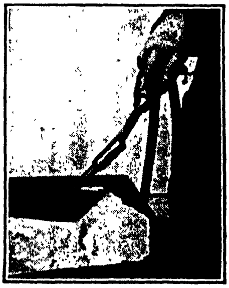


Fig. 22. Blowpipe Should Not Travel Backwards

Inclination of Blowpipe. The head of the blowpipe should be inclined at an angle of about 60 degrees to the plane of the weld.

The inclination of the head should not be too great, Fig. 20, because the molten metal will be blown ahead of the welding zone and will adhere to the comparatively cold sides of the weld. On the other hand, the welding head should not be inclined too near the vertical, Fig. 21, or the secondary flame will not be utilized to its full value for pre-heating the metal ahead of the actual welding.

In ordinary welding practice it is best that the top of the blowpipe be so inclined and so directed that the maximum amount of preheating is obtained without blowing the molten metal ahead.

Travel of Blowpipe. The travel of the blowpipe should be away from the welder and not toward him, Fig. 22, as the work can be observed more closely and done more easily and quickly.

Movement of Blowpipe. In making a weld a simultaneous fusion of the edges of the parts to be joined and the welding rod is necessary. If this does not occur, a true weld is not produced.

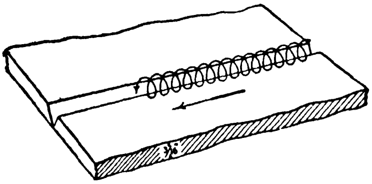


Fig. 23. Circular Motion of Blowpipe for Welding Light Sections

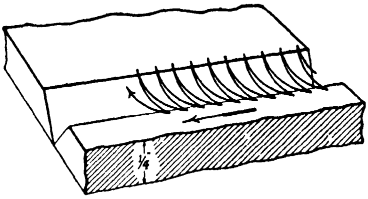


Fig. 24. Oscillating Motion of Blowpipe for Welding Heavy Sections

In the case of parts which have been chamfered out and which require the use of filling material, a peculiar motion must be imparted to the blowpipe, which will take in both edges of the weld and the welding rod at practically the same time.

In comparatively light work a motion is imparted to the blowpipe which will cause the incandescent cone to describe a series of overlapping circles, as shown in Fig. 23. This overlapping extends in the direction of the welding. This motion must be constant and regular in its advance so that the finished weld will have a good appearance. The speed of progress should be such that complete fusion of the three members referred to is secured. The width of this motion is dependent upon the size of the material being welded and varies accordingly with the nature of the work. It does not take much experience to establish the proper size motion and the proper rate of advance for the various sizes and kinds of metals.

In very heavy work, if the above system were used, a great deal of the motion would be superfluous. Consequently, a movement in which the cone of the flame will describe semi-circles should be used, as shown in Fig. 24. This confines the welding zone and concentrates the heat. While the progress is not so fast, it is more thorough than the other system for this class of work.

Importance of Movement. To the average beginner the regular control from these motions is difficult. It requires considerable practice and experience to become skilled in this, but it is the regularity of these motions that produces the characteristic rippled surface of good welding. The progress of a welder and the quality of his work can be determined to some extent by the skill with which he produces this effect.

Position of Welding Rod. After the beginner has mastered the peculiar motions of the blowpipe, his next step will be to properly introduce the welding rod into the weld in such a manner that the regular advance of the blowpipe will not be hindered or retarded.

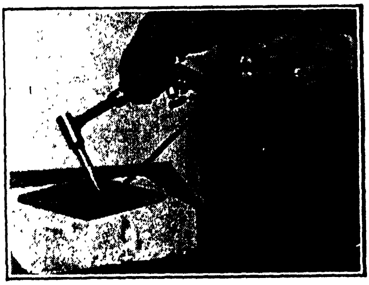


Fig. 25. Correct Method of Holding Welding Rod

The welding rod, or wire, should be held and inclined, as shown in Fig. 25. In this position a sufficient quantity of material may be added at the right time. If the welding rod were held in a vertical or horizontal position, the welder would be liable to add an excess of metal, part of which would not be properly fused.

When to Add Welding Rod. Great care must be taken in adding this metal that the edges of the weld are in their proper state of fusion to receive it. If the metal is not hot enough, the added material will simply adhere to the sides, resulting in adhesion only, not a true weld. It is, therefore, necessary to produce equal fusion at the edges of the weld with that of the welding rod by the correct motion of the blowpipe.

How to Add Welding Rod. When the proper time arrives to add the filling material, the welding rod is lowered into the weld until it is in contact with the molten metal of the edges. When in this position the flame of the blowpipe is directed upon it, and thus fusion is produced.

In welds of unusual depth the end of the rod is immersed in the molten metal and the blowpipe flame is played around it. The material is thus protected from the air and the gases of the blowpipe. The heat of fusion in this case is supplied mostly from the molten metal which surrounds the rod.

Faults to Be Avoided. The usual faults of the average beginner are: first, failure to introduce the welding rod into the welding zone at the proper time; second, to hold the rod at the wrong angle; and third, to fuse either too little or too much of the rod. The filling material when melted should never be allowed to fall into the weld in drops, or globules, Fig. 26.

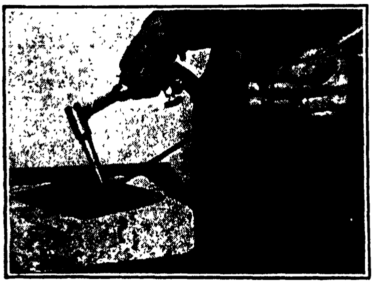


Fig. 26. Welding Rod Should Not Be Allowed to Fall into the Weld in Drops

Building Up the Weld. In welding it is customary to build up the welded portion in excess of the thickness of the original section. There are several reasons for doing this. First, the weld is reinforced and the strength is accordingly increased. Second, in case it is desired to finish the surface there is sufficient stock to allow machining. Third, in some cases small pinholes or blowholes may be found just under the surface of a weld, which do not extend to any depth in the weld and may be removed by filing or machining.

GENERAL NOTES ON WELDING

The above are basic principles involved in producing all good oxy-acetylene welds. There are many detailed operations which must be learned by practice for the successful handling of the different metals, but by keeping in mind these basic principles and by applying them properly, the more difficult operations can be readily mastered.

Haste Fatal to Good Welding. It is a fundamental rule for successful welding that the operator must give his undivided attention to the work in hand. *Do not try to hurry over or slight any step of the work.* You cannot weld faster than the metal will melt and fuse together.

Burning a Hole in the Metal. Occasionally an operator becomes so interested in some minor detail of his work that he allows the flame to burn through the metal and form a hole.

How to Weld Up a Hole. It is a difficult operation for a beginner to fill these holes. His first attempts usually result in enlarging the holes instead of closing them. The proper way to take care of this is to incline the blowpipe so that the flame is almost parallel to the surface of the work, Fig. 27. With the blowpipe in this position, play the flame upon the upper edge of the hole until the sides become plastic, taking care that the edges do not become entirely fused. When the edge is in the proper condition, the welding rod is interposed and a small amount of metal is added to the top edge of the hole. This operation is repeated until the hole is filled in. As the work progresses, the blowpipe is gradually raised until it resumes its normal position.

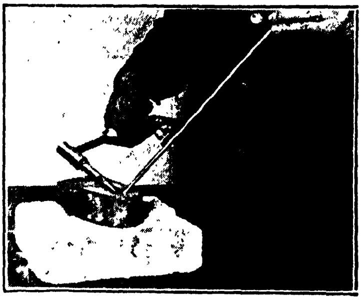


Fig. 27. Method of Filling in a Deep Hole—Start at the Upper Edge

Overhead and Vertical Welding. In welding overhead, Fig. 28, or vertically, Fig. 29, the same procedure is followed as in filling a hole. The metal should not be allowed to reach the state of fusion that is secured in ordinary welding. It should be hot enough to assimilate the welding rod, but not so fluid that it will flow out of the weld. In overhead welding care should be taken that oxidation does not occur, because the molten oxide will flow from the weld and seriously inconvenience the operator.

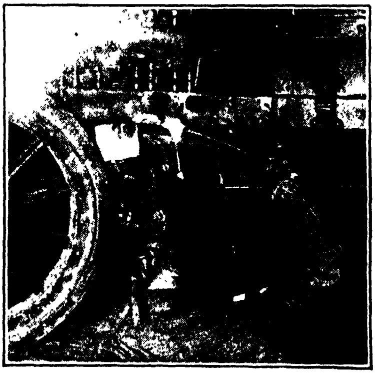


Fig. 28. Overhead Welding

Beginning a Long Weld. In beginning a long weld pains should be taken to see that it is started properly, and at this point of the work time should not be spared. When the weld is properly started the speed may be increased. As the weld advances the speed becomes

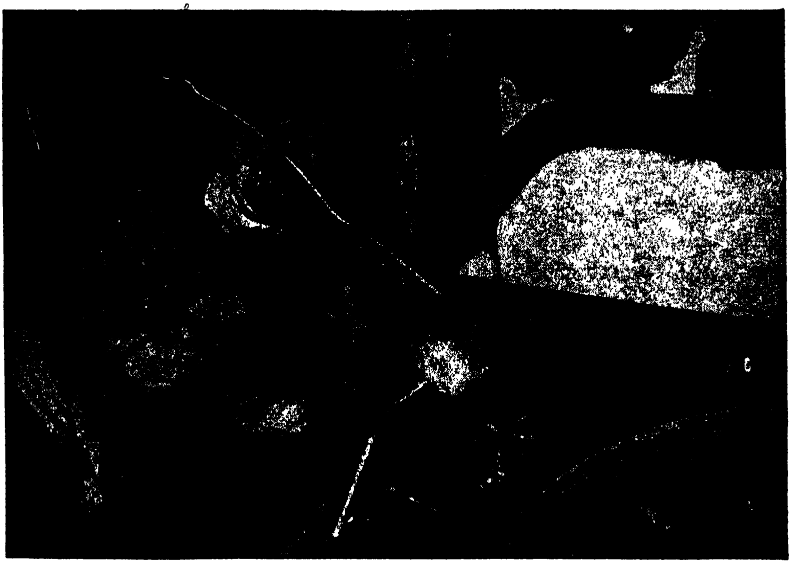


Fig. 29. Vertical Welding

greater, because the material becomes heated up and the blowpipe action is faster.

Defects in Welds. There are a number of sources of defects in welds, and the average beginner usually encounters all of them before he becomes a skilled welder.

Improper Flame Adjustment. If the flame is not properly adjusted the weld will be inferior. The commonest fault is the presence of too much oxygen in the welding flame. Unless the operator takes a great deal of care in removing the oxidized particles, they will be incorporated in the weld, Fig. 30. The oxide, of course, greatly decreases the strength and greatly affects the other mechanical properties of the weld.

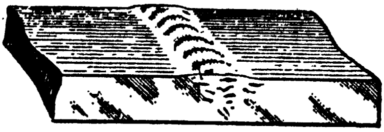


Fig. 30. Oxidized Weld

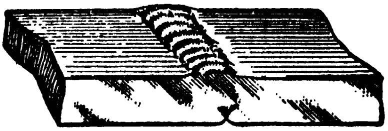


Fig. 31. Failure to Completely Penetrate to the Bottom of the Weld

Failure to Penetrate. A fault, not only of the beginner but also of the skilled operator, is failure to penetrate to the bottom of the weld, Fig. 31, and is the cause of a great many defective welds. In his desire to complete a weld as soon as possible, the operator very often hastens over the most important part of the work, which is to secure the absolute fusion of the edges at the bottom of the weld. Failure to do this not only reduces the section of the metal at the weld, but also gives a line of weakness in case the welded pieces are submitted to bending or transverse strains.

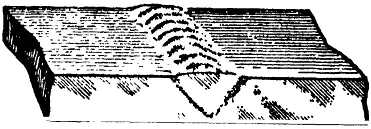


Fig. 32. Adhesion of Added Metal to Edges of the Weld

Adhesion of Added Metal. When molten metal from the welding rod is added to the edges of the weld which are not in fusion, a weld is not secured. The added metal merely adheres to the cooler metal, Fig. 32, and perfect fusion is not secured. Adhesion may be caused by improperly chamfering the pieces to be welded, by improper inclination of the blowpipe, by improper use of the welding rod, or by faulty regulation and manipulation of the welding flame.

The tendency of beginners is to not prepare the pieces properly for welding. Usually the chamfering, or grooving, is either not deep enough, that is, does not extend entirely through the section to be welded, or it is not wide enough. In welding pieces improperly prepared the tendency of adhesion is great.

The most common fault is the addition of the welding rod to the edges of the weld before they are in fusion. The adhesion in this case is applied to both edges. Sometimes one edge of the weld is in fusion. but the other is not. In this case adhesion is applied to only one side, but with the effect that the strength of the weld is lessened the same as when adhesion occurs on both sides.

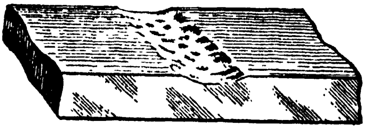


Fig. 33. Weld *Not* Properly Reinforced

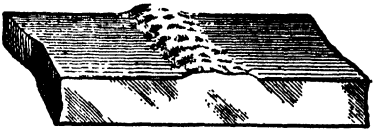


Fig. 34. Weld Properly Reinforced

In some cases the edges of the metal are brought to a state of fusion too soon, so that oxide has an opportunity to form on the edges of the weld. Then, when the welding rod is added, adhesion occurs with a film of oxide separating the edges and the added material.

Often an operator will concentrate the flame upon the welding rod and the edges of the weld. Then, as the blowpipe is played around the welding rod, some of the molten metal is forced ahead. The metal ahead is not in the proper state of fusion and consequently adhesion results.

Insufficient Reinforcing. It is not uncommon to see welds produced that do not contain enough metal, Fig. 33. All welds should be reinforced with additional metal as in Fig. 34. In case a smooth finish is desired this excess metal can be removed by grinding or machining. Too great an excess of metal must not be added because this takes extra time and the gases are wasted.

OXY-ACETYLENE WELDING PRACTICE

PART II

WELDING FOR DIFFERENT METALS

PROPERTIES OF METALS

Before the beginner takes up the actual welding of metals, it is necessary that he study their properties, peculiarities, and behavior under the action of the welding flame. The ability of the repair man to recognize the different kinds of metal will be a great help in deciding the treatment of the metal during the process of welding. Certain metals are used for certain purposes so that the part that is to be welded is often a good indication, in itself, of the metal used. For instance, good cast iron is used for cylinders, pistons, brackets, covers etc., or where its brittleness is no detriment to its satisfactory operation in service. Some of the physical properties of the more common metals are given in Table I.

Melting Point. The first property that the welder should consider is the melting point or temperature at which the metal will fuse or become fluid. The average welder is usually fairly familiar with the difference in melting points of lead or zinc, and iron or steel; but he is usually not familiar with the difference between the melting points of brass, bronze, copper, white cast iron, gray cast iron, etc. This knowledge is especially important if it becomes necessary to weld members of dissimilar materials.

Thermal Conductivity. The conductivity of a metal is its ability to transmit heat throughout its mass. This property, which is not the same for all metals and varies within wide limits, is of great importance to the welder. It can be seen that if one metal conducts or transmits the heat from the welding blowpipe more rapidly throughout its mass than another, it is necessary that allowance be made both as to the pre-heating equipment and the size of the blowpipe used.

In welding metals of high thermal conductivity, it is necessary to use oversize blowpipes—as in the case of copper. Although the melting point of copper is low, yet the conductivity is high, and, consequently, a blowpipe of the same size as would be used on a similar section of steel must be used.

The conductivity of a metal will have a great bearing on the consideration of expansion and contraction. If one metal absorbs or leads the heat away from the welding blowpipe more rapidly than another, the heated area will become very much larger, and, consequently, the expansion and contraction more severe.

Specific Heat. The specific heat of a metal is the amount of heat that is absorbed when it is raised through a certain range of temperature. A metal having a low melting point but relatively high specific heat may require as much heat to bring it to its point of fusion as a metal of high melting point and low specific heat— as in the case of aluminum compared to steel.

Coefficient of Expansion. The linear increase per unit length when the temperature of a body is raised through one degree is its coefficient of expansion.

The coefficient of expansion varies materially with the different metals. Of the metals most commonly welded, as seen from Table I, aluminum has the greatest expansion, bronze and brass next, then copper, steel, and iron. Aluminum expands almost twice as much as iron or steel, consequently, in dealing with aluminum work it is necessary that this feature be considered very seriously.

Expansion and Contraction. When a body of any material is subjected to an increase in temperature, it expands and its volume and linear dimensions are increased. When the temperature is lowered a reverse action takes place, the body contracts, and its volume and linear dimensions decrease. Metals or metallic bodies are very susceptible to this change in volume due to variations in temperature.

The effect of this expansion and contraction is of great importance to the welder. It is impossible for the welder to produce satisfactory work until he has a knowledge of the nature and the amount of expansion usually encountered and of how to compensate for it.

The expansion and contraction of the welded piece cannot be controlled or arrested mechanically, because the force of expansion is irresistible. In malleable, or ductile, metals the expansion is liable to produce warping or deformation of the piece, while in materials that are not of this nature—brittle materials—such as cast-iron, the result of the expansion and contraction, unless properly taken care of, is fracture.

If the expansion can take place in all directions, it will give the welder no trouble, as the piece will expand equally all over, and upon cooling will contract to its original volume. If, however, the welding takes place at a point that is confined by various parts or by the particular construction of the piece, it is then necessary to give it due consideration.

The resultant effect of contraction, produced by the cooling of the welded object, must be considered equally with that of expansion. Contraction produces as much cracking, or checking, and warping as does expansion. Therefore, it is essential that the welder study not only the effect of expansion, but also the subsequent result produced by contraction.

Methods of Handling Expansion and Contraction. There are many ways of taking care of expansion and contraction, such as heating the entire piece to a dull red heat, simultaneously heating opposing similar parts, and breaking the piece at certain points to allow free expansion and then re-welding at the break. If the material is ductile or malleable, it may be warped or bent out of shape to such an extent that the spring will take up completely the opposing force of expansion and contraction. This, however, entails an accurate calculation and should not be used except where no other means are feasible.

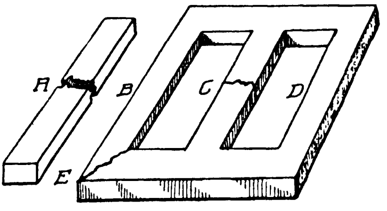


Fig. 35. Simple Case of Expansion and Contraction

Handling Simple Case of Expansion and Contraction. We will first consider the simplest condition of welding. Assume that a long bar which is free at each end has broken at point *A*, Fig. 35. In this case the welding may be carried out without any fear of encountering difficulties due to expansion and contraction. The bar is free to expand and contract at each end. While there might be some warping or deformation due to the heat of welding if the blowpipe is not handled properly, yet, there is very little danger of weakening the weld because of internal strains.

Now let us assume that this bar is part of a casting, as shown at *C*, which is surrounded and joined to a rigid frame *B* and *D*. In this case the expansion and contraction due to welding must be taken care of. It is readily seen that the expansion is not the force that will cause trouble, because when the two pieces expand during welding, the metal, which is in a fused condition, is so soft that the expansion can take place in the weld and the edges will approach each other. This will not affect the confined frame. However, consider the action on the metal when it starts to cool. Contraction sets in and, as it is irresistible, there must be some compensation for the shortening of the bar *C*. If the material is ductile and one that will stand bending, deformation or warping will occur. But, if it is of low ductility, such as cast iron, a break will occur either at the weld or at a line of less resistance.

Methods of Handling. In welding an article of the general nature, shown in Fig. 35, when the break is in an internal member, such as at *C*, there are several ways of handling it.

Heating Entire Casting. The entire piece can be raised to a high temperature as referred to above and in this way produce an expansion in the entire mass, and, consequently, equal contraction. However, this is not necessary, and in some cases is not possible; the operation also takes more time and costs more. It is only necessary at the time of welding to heat simultaneously similar parts to a good red heat, in order that the stiffness of the frame may be lessened, and thus take care of the contraction.

Heating Confining Members. In the example referred to, the application of a pre-heating burner at the points *B* and *D* will cause the frame to expand in the linear direction of the expansion and contraction produced by the weld. Therefore, when the weld is finished and the frame starts to cool and contract, the parts *B* and *C*, in as much as they were raised to practically the same temperature as the metal surrounding the weld, will contract equally and, therefore, a successful weld will be produced.

Use of Wedges. If it is impossible to apply pre-heating at the points referred to, another method may be used. By the use of jacks, wedges, or similar devices, a casting such as shown in Fig. 35 may be sprung or bent out of shape, and the edges of the part to be welded may be separated. After the weld is executed and contraction sets in, the jacks, wedges, etc., may be withdrawn. The return of the sprung parts to their original positions will compensate the contracting strains.

Breaking Another Member. Another method of taking care of expansion and contraction is that of breaking the piece at some extraneous point, such as at *E*. In this case the expansion and contraction will be free to act at the point *C* without any fear of serious after-effect, as the casting is free to spring in any direction, because of the loose joint at *E*. As the point *E* is not confined, it is an easy matter to reweld this break without fear of any bad results. This method, however, is dependent upon the thickness of the metal and is one that should not be attempted unless no other means are feasible.

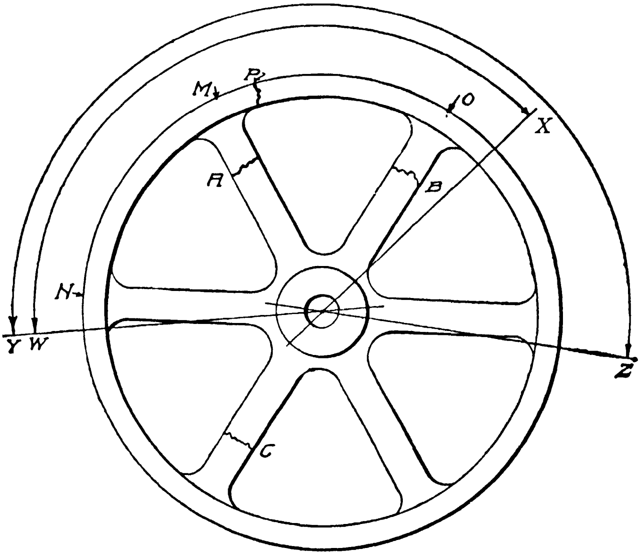


Fig. 36. Complex Case of Expansion and Contraction

While this diagram is extremely simple, nevertheless the principles to be considered and the methods of handling them are indentical with those experienced in all practical work. A clear conception of the forces acting, the nature of their action, and how to counteract them, is essential in work with the oxy-acetylene blowpipe.

Handling Complex Case of Expansion and Contraction. A good example of a complex case of expansion and contraction is the flywheel or pulley with broken spokes, as shown in Fig. 36.

Assume that the spoke is broken at *A*. If this were welded without considering and allowing for expansion and contraction, the shrinkage strain would be so great that failure would occur.

Pre-heating the rim from *W* to *X* to a dull red heat will cause the rim to expand outwardly, separating the edges of the broken spoke. While in this state the weld should be made rapidly and then the entire wheel allowed to cool slowly. Thus a good weld without the presence of internal strains will be produced. The expansion of the rim, due to the pre-heating, will offset the contraction of the weld in the spoke.

If the crack in the spoke is near the rim, it is only necessary to apply a gas or oil burner to the rim at *M* until it is at a red heat. This will expand the spoke and rim, and separate the edges of the break sufficiently to offset the contraction of the weld.

The spoke may be welded at *A* without pre-heating if the confining member—in this case the rim—is broken to lessen the rigidity. In order to do this the rim must be broken at a point *P*, always close to the spoke. First one side of the spoke is strongly tacked at the weld. Then the other side is welded two-thirds the way through. The tack is then melted out and the weld completed. The rim is then welded at point *P*. If the edges do not meet accurately, they may be brought to do so by heating either at *M* or *O*, according to which edge is low.

If two spokes are broken as at *A* and *B*, the same general procedure as given above may be followed. In case it is necessary to pre-heat a large portion of the casting it is important that the pre-heated area always extend beyond the spokes adjacent to those fractured, from *Y* to *Z*.

If two diametrically opposite spokes are broken such as *B* and *C*, each may be treated as independent of the other and welded by any of the methods given above.

PRE-HEATING

Reasons for Pre-Heating. Pre-heating is employed for three fundamental reasons:

To Compensate for Expansion and Contraction. When pre-heating is used to counteract the effects of expansion and contraction, it is necessary that the casting be heated either in certain confined localities or entirely to a dull red, or in some cases to a bright red heat. With this treatment the internal strains existing in all welds are reduced to a minimum.

To Decrease Cost of Welding. When a weld is being executed on a large casting, it is too expensive to supply the total amount of heat required from the blowpipe alone. To offset this, pre-heating by some cheaper method is used, and the result is usually a saving of from 25 to 60 per cent of the cost of welding by means of the blowpipe alone. Then, too, it is possible to accomplish the welding with greater speed, due to the casting being at a higher temperature.

To Make Metal More Receptive to Action of Welding Flame. When the temperature of a metallic body is raised, the state of the metal surrounding the weld is more nearly that of the molten metal in the weld, and the result is a more homogeneous and smoother-grained union, dependent upon the temperature reached in pre-heating.

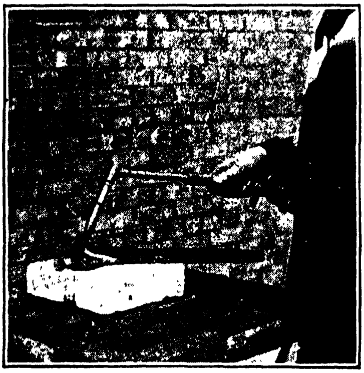


Fig. 37. Pre-Heating with Welding Blowpipe

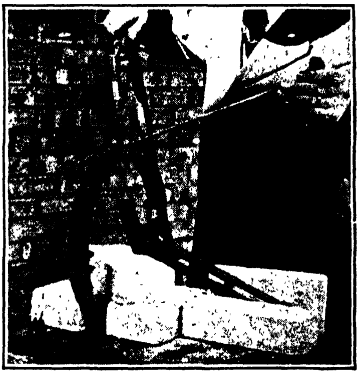


Fig. 38. Gas Burner for Pre-Heating

Methods of Pre-Heating. There are various means of carrying out this preliminary heating. The method used should be governed by the particular work in hand.

Pre-Heating with Welding Blowpipe. The simplest method and the one most used on light objects is that of utilizing the flame of the welding blowpipe, Fig. 37. In welding thin castings, it is only necessary that the flame of the blowpipe be played upon the parts at the line of the weld for a few moments, in order that the pieces may obtain a red heat. This is, however, expensive, and should only be employed on small objects.

Gas and Oil Burners. If the article to be welded is of fairly large size, the use of gas, Fig. 38, or oil burners, Fig. 39, is economical.

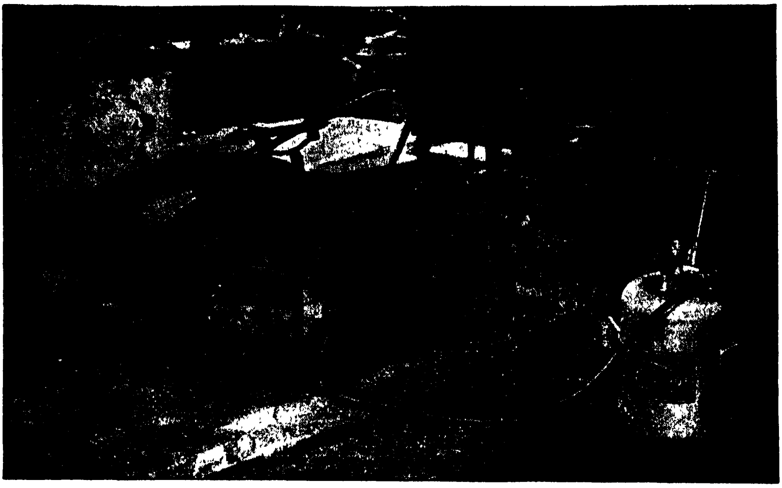


Fig. 39. Oil Burner for Pre-Heating
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

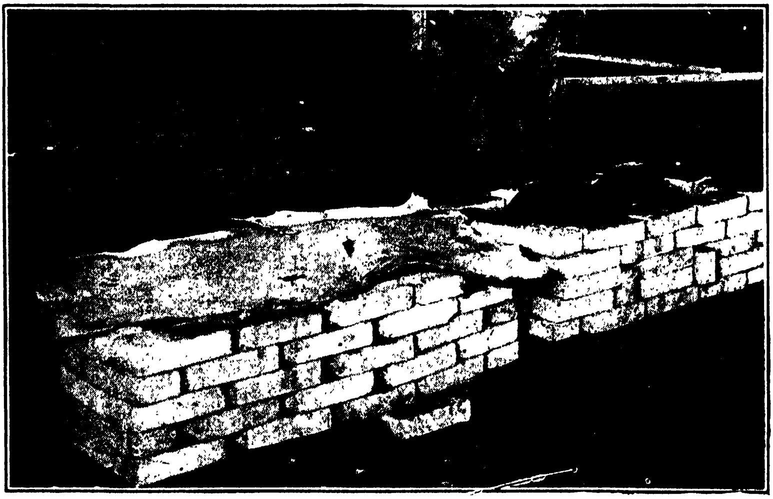


Fig. 40. Charcoal Fire for Pre-Heating Castings

These pre-heating torches, however, limit the area of the surface covered, so consequently are used more successfully on that work which requires localized pre-heating. The flames produced are of sufficient temperature, but not the necessary volume to evenly heat the entire casting.

Charcoal Fire. The most satisfactory method of pre-heating is by means of a charcoal fire built around the article to be welded. The usual procedure is to build a small temporary fire-brick furnace around the piece and fill in with charcoal, Fig. 40. This is ignited by means of kerosene. As the progress of the ignition of the charcoal is rather slow, the pre-heating is carried out gradually. The nature of this pre-heating flame is of such evenness and volume that the temperature imparted to the casting is the same throughout its mass.

In welding large castings of a complicated nature, such as engine cylinders, it is necessary that they be pre-heated evenly throughout and that the welding be carried on while the casting is at a dull red heat. Therefore, the most satisfactory means of accomplishing this is by embedding the casting in charcoal and carrying on the work while it is embedded in the hot coals.

STEEL WELDING

General Considerations. The welding of steel is apparently simple, but in reality it is a fairly difficult material to weld and should receive the welder's best thought and care. It is simple to produce a nice looking weld that has a smooth even surface, but it is not easy to produce a weld that is strong and will stand up under service. Welds of high strength are absolutely necessary in cases like automobile frame and crankshaft repairs, because a poor weak weld might prove fatal.

Oxidation. It is practically impossible to prevent a certain amount of oxidation; but it is very important that it be kept to a minimum. The oxide that forms on the top of the weld may be removed quite easily, because it melts at a lower temperature than the metal. It may be floated off the weld while hot, or removed as a thin skin after the weld becomes cold. Care must be taken, when adding the welding rod, Fig. 30, page 32, Part I, that this film of oxide is penetrated, because if this is not done the oxide will be incorporated in the weld, which will therefore be very weak.

Expansion and Contraction. The effect of expansion and contraction is not as severe in steel welding as in cast iron or aluminum;

but, nevertheless, it must receive due consideration. In steel castings it is taken care of in a manner similar to that used for cast iron, that is, by pre-heating. In sheet-steel work the creeping, or drawing, of the edges is taken care of by arranging the edges of the sheets at an angle, or by tacking, or by the use of jigs to hold the work.

Welding Rod. Each welding head is designed for use with a certain thickness of metal. As the volume of the flame varies with the size of the welding head, care must be used to select a welding rod of the correct size in making welds in sheets of various thickness. There is great danger of burning a welding rod that is too small, or, if the rod is too large, it may not melt through and will enter into the weld in a semifused condition and not be thoroughly incorporated in the weld. The following table shows the proper size of welding rod to be used for the different thicknesses of sheets:

THICKNESS OF SHEET	SIZE OF WELDING ROD
Up to $\frac{1}{8}$ inch	$\frac{1}{16}$ inch
$\frac{1}{8}$ to $\frac{3}{16}$ inch	$\frac{1}{8}$ inch
$\frac{1}{4}$ to $\frac{3}{8}$ inch	$\frac{3}{16}$ inch
$\frac{1}{2}$ inch and over	$\frac{1}{4}$ inch

Never use twisted wire made up of two or more strands, because this offers a very large surface for oxidation, which is a condition operators must try to avoid.

Neutral Flame. The importance of maintaining a neutral flame at all times cannot be emphasized too strongly. An excess of acetylene in the flame tends to carbonize the work, resulting in a hard brittle weld; while an excess of oxygen will oxidize or burn the metal. It is seldom necessary to adjust the flow of gases through the blowpipe after correct adjustment has once been made, except in the case of very heavy welding where the intense heat of the molten metal tends to expand the orifice in the tip of the welding head. This has some effect on the size and shape of the flame and necessitates more or less frequent adjustment to keep the gases in correct proportion to maintain the neutral flame.

Movement of Blowpipe and Addition of Welding Rod. In welding sheet steel, it is necessary that the oscillating movement previously referred to be imparted to the blowpipe and used continuously—both because of its high-melting point and the behavior of the molten metal under the action of the blowpipe flame. Steel cannot be puddled and it is therefore necessary to add the filling material in thin overlapping layers. The importance of securing a perfect bond between every two layers can be readily seen. To make a true weld, a simultaneous fusion of the edges of the sheets and the welding rod must be produced.

To do this with light- and medium-weight sheets, a motion is imparted to the blowpipe which will cause the flame to describe a series of overlapping circles, page 28, Part I. This overlapping extends in the direction of the welding and, in order to make a weld of good appearance, must be constant and regular in its advance.

In heavier plates, while the same rule governing simultaneous fusing of the edges of the sheets and welding rod apply, the filling of the groove is accomplished in a slightly different manner. On account of the depth of the weld the flame is not large enough to fuse a body of metal of so great an area, and it is impossible to fill the groove entirely from bottom to top with one layer of metal. The bottom edges of the groove must first be thoroughly fused for an inch or two before adding metal. When this is done, bring the flame back to the starting point and when the metal is in the proper molten condition add the filling material, oscillating the blowpipe in a series of semicircles, as recommended for welding heavy sections, page 29, Part I. Follow this method of filling the groove in sectional layers until the proper height is reached, making sure that thorough fusion is accomplished between the layers themselves and the edges of the sheet and the layers of filling material.

After-Treatment. Correct after-treatment is as essential for successful welding of steel as the actual welding operation. Proper after-treatment will improve the grain of the metal and will materially increase the strength and toughness of the weld. There are three principal treatments that will benefit the material and are easily employed in the repair shop. These are called annealing, hammering, and quenching.

Annealing. Annealing consists of reheating the work to the proper temperature and then allowing it to cool slowly. The work should be heated to a bright cherry red by means of a blowpipe or suitable burner, or in a furnace that can be carefully regulated. Care must be taken that the work reaches the bright cherry red, because heating to a lower temperature will be detrimental and may leave the weld weaker than if not annealed at all. After the work has been heated, it should be allowed to cool very slowly and evenly. It should be covered over with asbestos or dry sand, packed in lime, or left to cool in the furnace. Care must be taken that cold air currents do not strike the work before it has become cold.

Hammering. Hammering consists of reheating the weld to the proper temperature and then hammering while at this temperature with a hand hammer. The weld should be heated to a bright yellow heat and then hammered with quick light blows. Heavy hammers or heavy blows should never be used. The hammering should cease as soon as the weld falls to a dull red, for otherwise the fine grain of the metal will be spoiled and the weld will be weak.

Quenching. Quenching consists of reheating the work to the proper temperature and then plunging it into water, brine, or oil. This method is used mainly for small articles. It is used quite often for hardening and tempering. Quenching should be employed only in special cases, because, although it will make the work strong, it will also make it hard and brittle.

Light Sheet-Steel Welding

Preparation. In welding two short pieces of flat steel, up to $\frac{3}{16}$ inch in thickness, no special preparation of the plates is necessary, except to have them flat as possible and to be sure that the edges are reasonably true. The two pieces of metal should be placed on a level surface, preferably fire brick or some other nonconductor of heat.

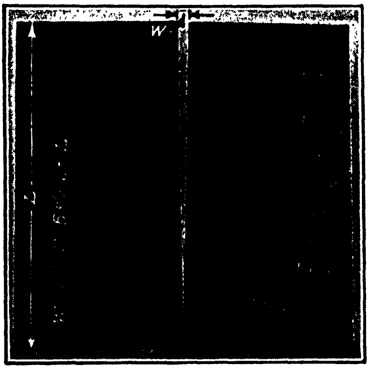


Fig. 41. Light Sheets in Position for Welding

Expansion and Contraction. With light sheet, expansion and contraction are cared for by tacking the seam at certain intervals or by arranging the sheets so that the edges to be welded are set at a slight angle rather than parallel, Fig. 41. The correct amount of divergence is determined by the thickness of the metal and should be from 2½ to 6 per cent of the length of the weld. The amount of divergence between these limits varies also with the speed of welding, fast welding requiring less spread. After the plates are in this position, place two pieces of flat bar steel on each side, about ½ inch from, and parallel to, the line of the weld. Clamp or weight these pieces down so that they cannot be readily moved. The work is now in position for welding.

Jigs. In making this type of weld in flat sheet steel in longer lengths, up to several feet and up to $\frac{3}{16}$ inch in thickness, a welding jig made up with two slotted jaws hinged at one end and provided with hold-down clamps at the other end will be found more convenient than the individual hold-down bars.

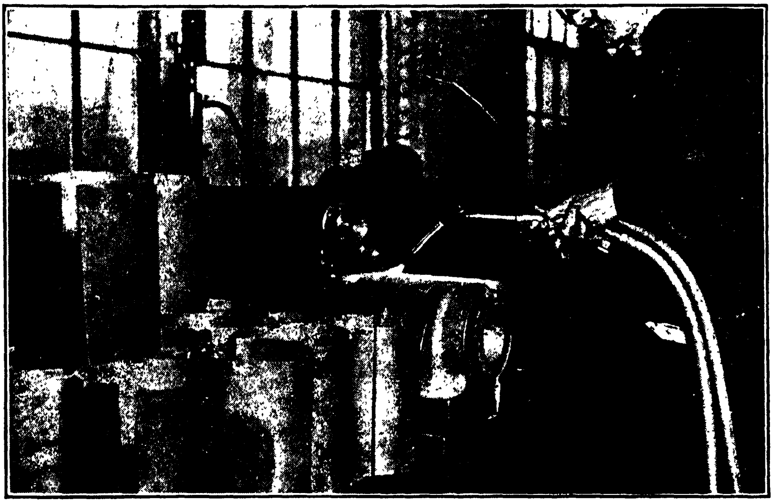
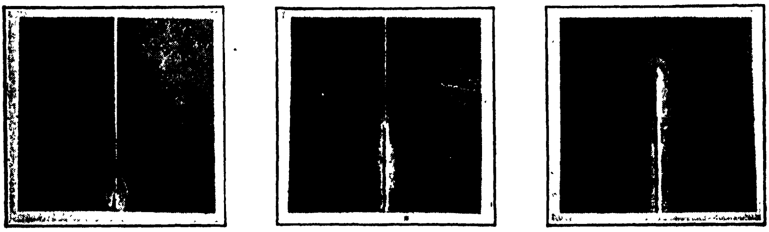


Fig. 42. Jig for Holding Light Sheet Cylinders for Welding

For welding short cylinders, a jig made similar to that shown in Fig. 42 will be found satisfactory.

Tacking. Tacks, or short welds, at intervals of from 2 to 6 inches, according to the thickness of the sheet, can be made the entire length of the seam to hold the edges in position for welding if jigs are not available.

One of the above methods must be used to take care of the creeping action due to expansion when the flame of the blowpipe is applied to the metal. If this action is not provided against and the two sheets are placed with parallel edges, they will first diverge when the welding is started, as in *a*, Fig. 43, and then gradually come together. When about half of the weld has been made, they will again become parallel as in *b*. From this point on as the welding continues the sheets will draw together until they overlap, as shown in *c*.



(*a*) (*b*) (*c*)

Fig. 43. Result of Not Providing for Expansion

Welding Light Sheet. Select the welding head and a piece of iron welding rod of the size suitable for the thickness of the sheet and place the work in position for welding.

As steel is very sensitive to the action of the carbonizing flame and particularly to that of the oxidizing flame, a constant, nonvarying, neutral flame should be maintained. The incandescent jet should be of maximum size and clear outline at all times.

With the correct neutral flame, start welding at the point where the two sheets meet. Impart the circular motion to the blowpipe, described on page 28, Part I, to produce the correct rippled surface on the finished weld. When the weld is finished, turn out the blowpipe and allow the work to cool until the metal is black.

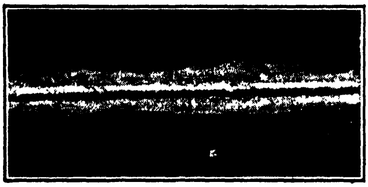


Fig. 44. Appearance of Good Weld in Light Sheet Steel

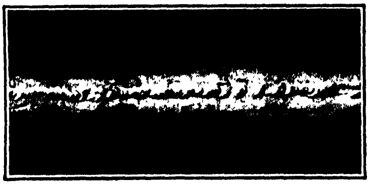


Fig. 45. Appearance of Poor Weld in Light Sheet Steel

Then remove the hold-down bars and examine the weld. If you have followed instructions, your weld will have the appearance shown in Fig. 44 and will not be like that shown in Fig. 45. On closer examination you will find that all the particles of dirt and impurities you noticed floating on the top of the molten metal when you were welding are now lying with the oxide on top and alongside of the weld where they can be readily brushed or scraped off. Now take your job to the shears and cut off one or two pieces. Upon examination, the cross-section should present the same uniform texture and color in both the weld and the sheet.

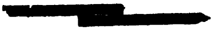


Fig. 46. Lap Welds Should Never Be Used

Types of Welds in Light Sheet. *Lap Weld.* Lap joints, either single or double, Fig. 46, *should never be used* in welding sheets of any thickness because the weld will be subjected to a shearing strain.

Welds should be under tension or compression strains, never under shearing or bending strains.

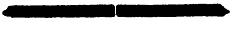


Fig. 47. Butt Weld in Light Sheet

Butt Weld. The most common and the simplest weld to prepare in light sheet is the butt joint, shown in Fig. 47.

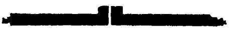


Fig. 48. Flange Weld in Light Sheet

Flange Weld. Another type of weld in light sheet, but one that entails some preparation, is made by flanging up the welding edges about $\frac{1}{32}$ to $\frac{1}{16}$ inch, Fig. 48, laying the two pieces flat and parallel on the welding table and executing a flange, or edge, weld. It is not necessary to use welding wire with this type of weld, because the metal in the flanges when they are fused together acts as a filling agent. By careful manipulation the edges can be fused down to a small bead, practically flush with the surface of the sheet.

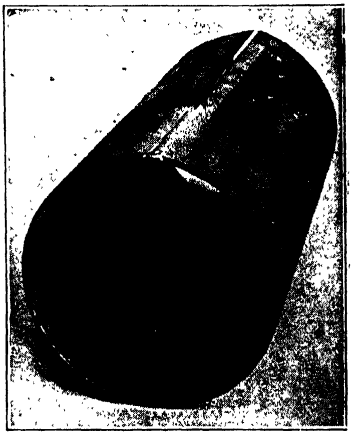


Fig. 49. Method of Welding Light Sheet Cylinders—Using Wedge to Space the Edges

Cylinders. In welding light sheets that have been rolled in cylindrical form, the separation of the edges can be accomplished by placing a wedge about two-thirds of the way down the length of the seam after the welding is started, Fig. 49. As the welding progresses the wedge should be moved further along the seam and withdrawn entirely as the work nears completion.

Tacking can also be resorted to in welding cylindrical forms, although this results in the deformation of the cylinder, as shown in Fig. 50, and makes it necessary to hammer or re-roll the cylinder into shape.

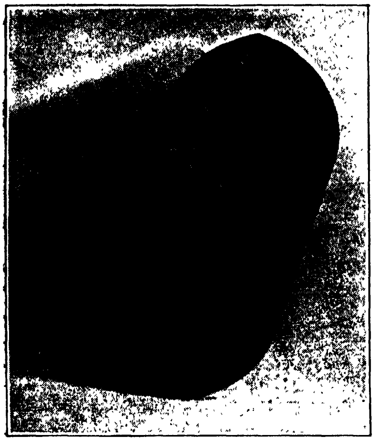


Fig. 50. Result of Tacking a Light Sheet Cylinder—The Weld Draws up Pointed

The edges of very light sheet cylinders can be flanged and an edge, or flange weld, executed; but this method cannot be recommended with sheets heavier than $\frac{1}{16}$ inch.

Corner Welds. In making a corner weld in the lighter gage sheets up to $\frac{1}{16}$ inch, the edges of the sheet should be flanged, as shown in Fig. 51. In sheets from $\frac{1}{16}$ to $\frac{3}{16}$ inches in thickness, it is only necessary that the edges of the sheets run as true as possible in position, as shown in Fig. 52. Tacking is necessary in this case, as the sheets, due to expansion, readily move out of position when welding is commenced. On welds of this latter type it is necessary to use welding wire.

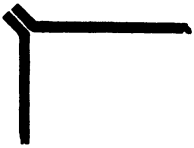


Fig. 51. Corner Weld for Very Light Sheets, up to $\frac{1}{16}$ Inch Thick

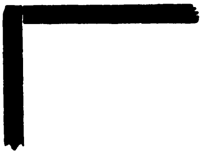


Fig. 52. Corner Weld for Light Sheets, $\frac{1}{16}$ to $\frac{3}{16}$ Inch Thick

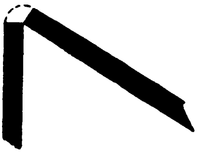


Fig. 53. Sharp Corner Weld for Light Sheets

Two other forms of corner welds are illustrated in Figs. 53 and 54. These sheets should be tacked and, if $\frac{1}{16}$ inch or thicker, welding wire should be used.

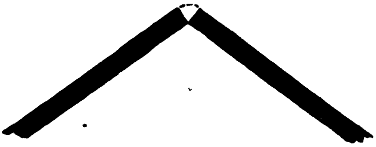


Fig. 54. Broad Corner Weld for Light Sheets

Tank Heads. In making tanks when either a bottom or heads in both ends are required, the method of putting in the heads is governed by the design and purpose for which the tank is intended.

Storage Tanks. If the tank is to be used as a storage receptacle, such as gasoline tanks, the heads can be cut to the outside diameter of the shell, laid flat on the end of the shell and tacked at intervals all the way around, Fig. 55. Then the shell, with the heads securely tacked in place, is laid on its side and the welding is started at any point, the tank being turned, from time to time, as the welding progresses. Or, the heads can be flanged to any depth desired, and backed into the shell until the edge of the flange and the edge of the shell are even, Fig. 56, making sure that the head fits the shell snugly. They are then tacked and welded in an upright position. This latter method is the better of the two from the welding standpoint.

Pressure Tanks. When a tank is built to stand a considerable pressure, such as air-compressor tanks, the heads should always be dished and flanged, the boiler-maker's standard specifications govern this. The heads can be either backed in and an edge weld made, Fig. 56, or set up so that the edges of the flange exactly meet the edges of the shell, Fig. 57. In either case the parts should be tacked together before welding. In the second case, care should be used in flanging to have the outside diameter of the flange exactly the same as the outside diameter of the shell. This method is the best because the weld is under direct tension or straight pull.

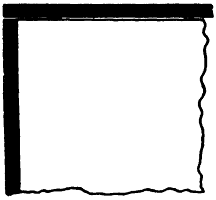


Fig. 55. Head Weld for Storage Tanks

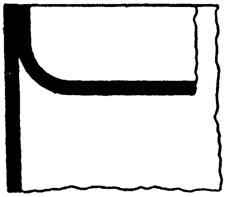


Fig. 56. Head Weld for Storage and Medium-Pressure Tanks

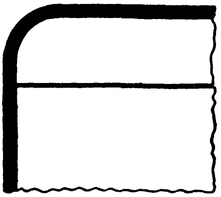


Fig. 57. Head Weld for Pressure Tanks

Tubes. Light-weight tubing should be squared off and fitted nicely before welding is attempted. It should be tacked in several places and then welded.

Heavy Sheet-Steel Welding

Preparation. In welding heavy sheet metal above $\frac{3}{16}$ inch in thickness, a certain amount of preparation is necessary. The success of the weld depends in a great measure upon the proper preparation of the work to be welded. While the preparation is governed largely by the particular location of the weld and form of the sheets to be welded, there are certain general rules that must always be observed.

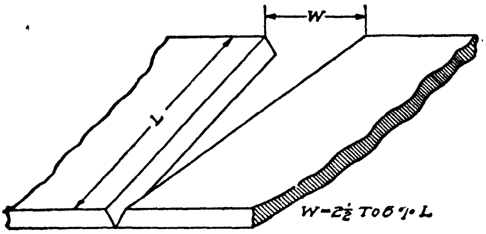


Fig. 58. Heavy Sheets in Position for Welding

In making a perfect weld it is necessary that the metal at the weld be completely fused throughout its entire thickness. In light sheets the projection of the flame is great enough to produce this result, but heavy sheets would require a flame of such magnitude that it could not be readily handled. Therefore, in order to facilitate complete fusion, the edges of the sheets to be welded are chamfered or beveled to form a V-groove, the width of this V being equivalent, or nearly so, to the thickness of the metal.

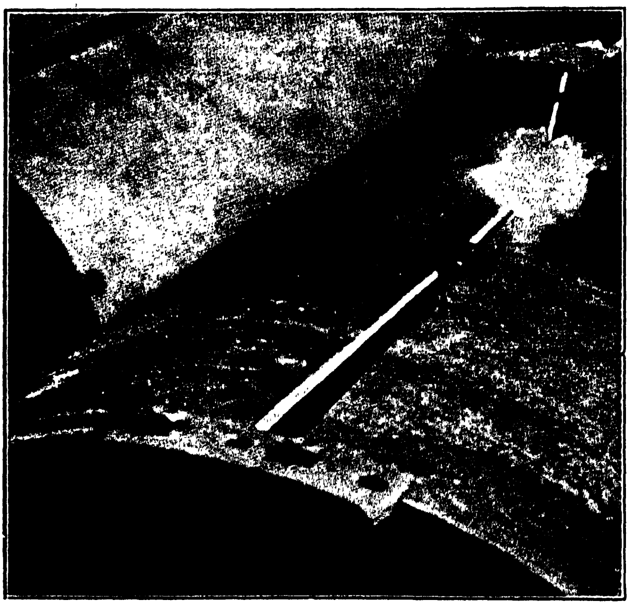


Fig. 59. Welding Heavy Plate Steel Cylinder
Note grooving of edges, spacing clamps and wedge about half way along the seam

Expansion and Contraction. With heavy sheet, expansion and contraction are cared for by observing the same rules of spacing, Fig. 58, and clamping, Fig. 59, or, in some cases, tacking, in order to hold the work in position for welding, as described for light sheets on page 47.

Welding Heavy Sheet. Select a welding head and a piece of iron welding rod of the proper size to accomplish the work in hand.

Because steel is sensitive to the carbonizing and oxidizing flames, it is necessary to maintain the correct oxygen pressure and a neutral flame at all times. In ordinary heavy sheet welding there are two general methods of procedure, either of which will produce a good weld when properly executed. These methods may be called welding by sections, and continuous welding.

Welding by Sections. Welding is started by first playing the flame of the blowpipe along the edges of the pieces to be welded. This is done merely as a preliminary heat treatment. The flame is then played on the bottom of the groove at the beginning of the weld until the edges are in a molten condition, at which time the blowpipe is momentarily withdrawn and the molten metal allowed to flow together. This is done without the aid of any filling material. Care must be exercised at this point, because successful welding depends upon complete penetration and perfect union of the bottom edges. When a perfect union of the two members is secured for about one or two inches, the welding rod is brought into use. By playing the flame around the welding rod in contact with the edges of the weld instead of directly on the welding rod, it is possible to bring them both to the point of fusion simultaneously. The rod is then gradually added to the weld, layer by layer, until this particular section of the weld is built up to the required height. The flame is then played on the face of the metal just added and on the bottom of the groove until fusion of these parts is secured. The welder then repeats the operation described above until the next small section of the groove is filled up to the proper level. The welding progresses by means of these small sections, each being built up completely before another is started.

While the metal is in a fused condition, the velocity of the flame will cause the molten metal to become slightly indented. The flame should be withdrawn momentarily, from time to time, thus allowing the fluid metal to flow back to its normal level, in which position it will solidify. Skill in steel welding depends greatly on this manipulation, as the flowing together of the different molten centers produces the weld.

Continuous Welding. In this method the weld advances continuously with each addition of metal. By this method the metal is added in short layers, sloping rather than horizontal. The weld is started by fusing together the bottom edges of the groove as previously described. The filling material is then added so that it will be from ⅛ to ¼ inch high at the starting point and slope to nothing in a length of 1 or 1½ inches along the bottom of the groove. This will give an inclined surface to which the filling material is added in parallel layers. The added metal being on a sloping plane, the fusion of the bottom edges is always carried ahead with the welding, as each layer includes a small section of the bottom of the groove.

Types of Welds in Heavy Sheet. *Lap Weld.* As explained on page 49, the lap weld *should never be used.*

Butt Weld. The beveled or grooved butt joint is the only welded joint that should be employed on heavy sheets, Fig. 60. The most satisfactory method of handling the work is to space the edges, because tacking is very likely to not hold on heavy sheets.

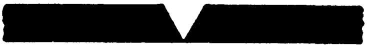


Fig. 60. Butt Weld in Heavy Sheets

Never weld sheets from both sides, because unequal strains are likely to be introduced by localized heating when working on the second side.

Cylinders. Heavy cylinders should also be prepared for the grooved butt weld, for the same reasons as for heavy sheets.

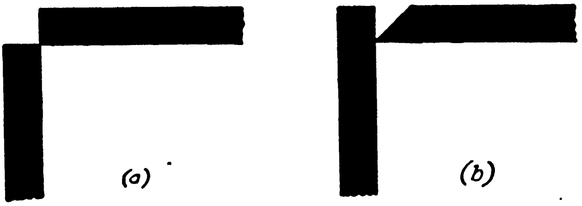


Fig. 61. Corner Welds for Heavy Sheets

Corner Welds. The two most satisfactory corner welds for heavy sheet are shown in Fig. 61. Although the second is a little more costly to prepare, it is more satisfactory than the first because it insures better penetration.

Tank Heads. In welding bottoms or heads in tanks of heavy sheet, the purpose for which the tank is to be used governs the method of constructing the heads as it does in welding tanks of lighter gage. The same general rules apply in both cases, the main difference being that the edges of the heavy shells and heads are chamfered, dependent on the design of the tank. All require tacking to hold the members in position for welding.

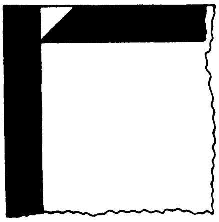


Fig. 62. Head Weld for Storage Tanks

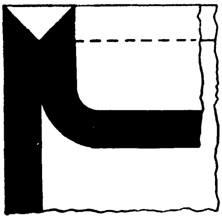


Fig. 63. Head Weld for Medium-Pressure Tanks

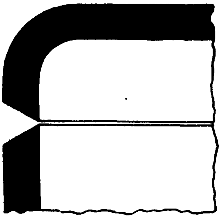


Fig. 64. Head Weld for High-Pressure Tanks

Storage Tanks. In the case of putting on a flat head, the edge of the head only is chamfered, Fig. 62, while in putting in a flanged head where an edge weld is to be executed, as in Fig. 63, both shell and head are chamfered to make the V-groove.

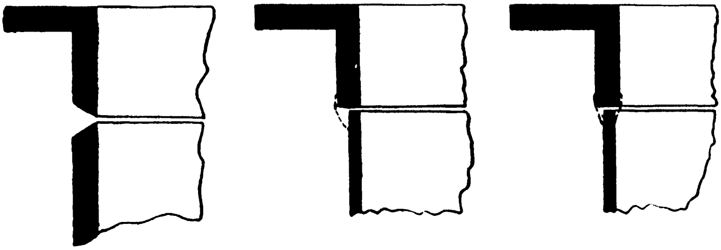


Fig. 65. Welds for Tank Reinforcing Rings

High-Pressure Tanks. When a head is put in, as shown in Fig. 64, both the edge of the flange and the edge of the shell are chamfered. This type of head is the best for high-pressure tanks because the weld is in tension.

This method also applies to the welding of two cylindrical shells end to end in making tanks of such dimensions that one single sheet of steel is not large enough to make a complete shell.

Tank Rings. In welding angle-iron rings to tanks of the same thickness, it is necessary that the edges of both ring and shell be beveled as at the left, Fig. 65. Two methods of welding heavy rings to lighter shells are shown at the middle and right. The inside weld at the right should be only enough to smooth off the joint. If too much heat is applied from the inside there is likely to be trouble from warping or buckling. Rings should always be tacked to prevent bowing, twisting of the rings, and buckling of the shell.

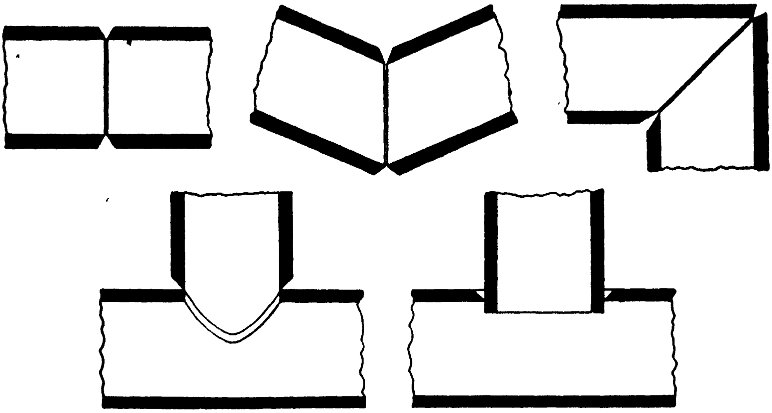


Fig. 66. Various Pipe Joint Welds

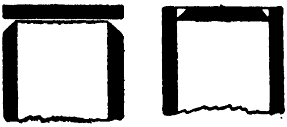


Fig. 67. Welds for Pipe Heads

Tubes and Pipes. Various tube and pipe welds are given in Fig. 66.

The methods for closing the end of a pipe with a head are shown in Fig. 67. The first is the easier and stronger of the two.

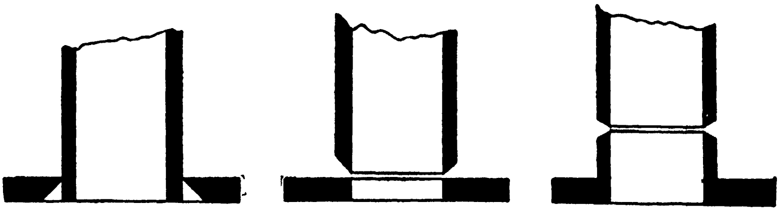


Fig. 68. Welds for Pipe Flanges

Three methods of welding flanges to pipe are shown in Fig. 68. The first method is easier to weld than the second; but the latter is the stronger. The third method is the best method of welding flanges to pipe, but is, of course, a special type of flange.

Welding Heavy Steel Forgings and Steel Castings

Preparation. In welding heavy steel sections, such as crankshafts, axles, and the like, the weld is prepared by grooving or beveling from both sides. This is done because it is easier for the operator to do the work and for the sake of economy, because by beveling from both sides less filling material is necessary and, consequently, less time and gas are needed.

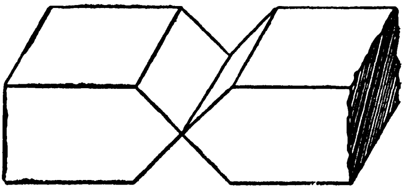


Fig. 69. Preparation of Heavy Forgings for Welding

Square Sections. Square or rectangular sections of forgings are best prepared by beveling half way through from each side, Fig. 69. After the welding has been carried on from one side, the piece turned over and the welding completed from the second side, there will probably be a slight bow, or curve. In the case of forgings, this is not objectionable, because the work can be, and, in fact, should be, reheated and straightened. The reheating in the case of forgings is beneficial to the grain of the material and the strength of the weld. With castings, however, this bending is not possible. Therefore, to keep the work in alignment, it is best to prepare the work as shown in Fig. 70. The welding is carried on two-thirds of the way through from the first side, and then finished by turning over and working from the second side.

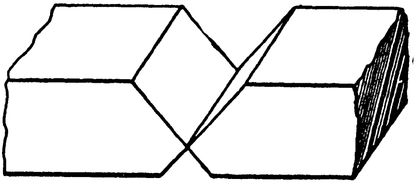


Fig. 70. Preparation of Heavy Castings for Welding

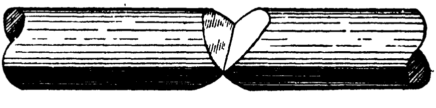


Fig. 71. Preparation of Round Sections for Welding

Round Sections. Round or elliptical sections should be prepared by beveling the ends to a wedge as indicated in Fig. 71. They should never be turned down to a point. By preparing the pieces as shown in the illustration, the welder will have a flat surface to build his weld upon. If the work were prepared to a point, the filling material when added would have no surface to lie upon and would run down in drops, necessitating burning or melting away when the work is turned over, and probably resulting in a weak weld with considerable oxide.

Expansion and Contraction. Expansion and contraction will probably cause very little trouble to the operator in the case of shafts and other heavy pieces that are not connected. The only difficulty the operator will encounter in these cases will be the possible bending, which was noted above, when welding from two sides. However, if the broken part is confined by rigid members, the work should be handled either by pre-heating, or one of the other methods recommended and explained under Expansion and Contraction, pages 36 to 40.

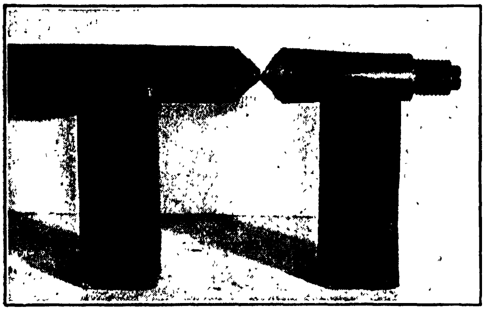


Fig. 72. "V" Blocks for Welding Shafts

V-Blocks. When welding shafts, it is advisable to line them up in position on V-blocks, so that they may be turned over and still kept in alignment, Fig. 72.

Welding Heavy Section. In the case of a heavy section select the proper size welding head and a piece of welding rod of the correct analysis for the particular work at hand, and place the work in alignment.

If the section is over or about one inch, it should be pre-heated by means of a gas or oil burner until it is at a red heat. This will save oxygen and acetylene, and will bring the material to a temperature at which it will be more receptive to the action of the welding flame and thereby insure a more homogeneous weld. If not objectionable to the operator, it is advisable to let the pre-heating burner play on the work while the welding operation is going on, taking care, of course, that the materials of combustion of the pre-heating burner do not strike the molten metal and have a detrimental effect on the weld.

The welding flame is first played on the edges at the bottom of the groove until they are in a molten condition. The flame is then momentarily withdrawn to allow them to flow together and "set", and form the bottom of the weld. When a perfect union of the bottom is secured all the way across, the welding rod is brought into use. By playing the flame around the welding rod and the edges of the weld instead of directly on the welding rod, it is possible to bring them to a fusing temperature at the same time. The rod is then gradually added to the weld, layer by layer, until the entire groove has been filled up. The welding rod is kept plunged into the molten metal all the time to prevent oxidation. Any oxide that forms during the welding is floated to the top and removed by scraping with the welding rod, or by blowing away with the force of the welding flame. The welder must be careful that he does not allow the molten metal to run over the sides of the weld. Each layer is added in such a way that it extends slightly beyond the end of the groove. Then, from time to time, as the groove is filled up, the operator smooths down the two ends.

Hammering. As each section, about ¼ inch thick, is added to the groove, the operator stops the welding operation, heats the work to a bright yellow, and hammers the weld lightly but rapidly to give it as fine a grain as possible. After the weld has been completed, it is either hammered or annealed, as directed on page 45.

CAST-IRON WELDING

General Considerations. Many defects are experienced by the beginner in welding cast iron because of its peculiar properties. The two principal faults noticed are the production of hard, glassy, and brittle metal in the weld, and subsequent cracks, breaks, and checks either in the weld or in the adjacent metal, owing to excessive internal strains set up by unequal contraction. Both are serious defects, and the liability of their occurrence is so great that proper preventive methods should be continually borne in mind and applied while welding this material.

Oxidation. Cast iron melts at about 2000° to 2190° F., and iron oxide melts at about 2450° F. The oxide is formed, however, at low temperatures, a bright red heat being sufficient to cause the combination of oxygen from the air with the iron of the casting.

It is not possible to melt this oxide and flow it from the weld, so it remains in the casting in the form of thin flakes or crust. This not only prevents the alloying of the molten metal, but also combines with the free carbon and is, consequently, conducive to the formation of white iron. Therefore, this oxide must be removed or destroyed.

Expansion and Contraction. Cast iron is absolutely lacking in elasticity, and its tensile strength is very low. In preparing work for welding, it is always necessary to take fullest precautions against the bad effects of expansion and contraction. Expansion and contraction should be treated with more importance in the welding of cast iron than in any other metal.

When the internal strain produced by contraction is greater than the tensile strength of the section to which it is confined, failure will occur. When the strain is not great, but still exists, the resistance of the section to external stresses is reduced in proportion. Thus a casting may appear to be normal after welding but the excessive internal strains caused by the welding may make it fail at the slightest shock.

One of the three general methods of coping with the forces of expansion and contraction, which are given on pages 36 to 40, must be used when welding cast iron. The proper method to pursue is determined by the size and shape of the casting and the nature and location of the break. A very large percentage of the failures due to shrinkage cracks may be prevented by an intelligent anticipation of the forces of expansion and contraction and the proper handling of the work to overcome these.

Pre-Heating. Pre-heating should be used to some extent in all cast-iron welding. If the piece is small and the break is so located that it is not necessary to consider expansion and contraction, the blowpipe should be played upon it until the chill is removed from the casting. If the casting is large, an oil or gas burner, or charcoal fire can be used. In a large casting this preliminary heat treatment not only favors the execution of a good weld but also requires less oxygen and acetylene because of this large volume of heat from a cheap source, thereby reducing the cost of welding.

Welding Rods. The success of cast-iron welding depends greatly upon the selection of a suitable welding rod. It has been proved time and again that hard, brittle, and weak welds have been produced for no other reason than because inferior filling material was used.

The presence of silicon in proper proportion tends to produce a soft gray-iron weld. It increases the fluidity of the metal, retards oxidation, and prevents decarbonization and blowholes. The success of the filling rod is dependent upon the amount of this element it contains. From 3 to 4 per cent is the average silicon content of good welding rods. The welding rod must be of high-grade cast iron, soundly cast and absolutely homogeneous. It must be free from all sand, grit, and rust. For convenience in handling, it is usually cast in 24-inch lengths of three diameters, $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$ inch. In case either a longer or heavier rod is desired, two or more are welded together.

Flux. The principal problem that confronts the welder is to prevent the formation of oxide, and in case it is formed, to reduce it and remove it from the weld. If this is not done, the molten metal will be enclosed in a thin film of nonmetallic material, and any additional metal that may be fused or added will adhere to this film rather than break through it and fuse homogeneously with the other metal. It is not possible to satisfactorily break up this film mechanically, therefore it must be reduced to a molten, or slag, condition. To accomplish this a suitable flux is used that will dissolve the oxide.

A flux is not used solely to dissolve the oxide, but also to float off other impurities, such as sand, scale, and dirt. It forms a protecting glaze on the weld and surrounding surfaces and increases the fluidity of the molten metal.

Borax and salt (sodium chloride) are two compounds often used by welders, but they really contain little merit as a flux. Their low fusibility seems to be the only point in favor of their use. Occasionally, they may be employed to advantage in welding heavy sections or burned iron, such as are found in firebox and grate castings, but their function is only that of a cleanser. Both tend to produce hard iron. There are certain flux powders put on the market that contain large proportions of manganese. These powders cannot help but have a hardening effect on the iron. Others contain potassium perchlorate, a violent oxidizing agent. Still others contain material that chlorinize the weld. Needless to say, powders of this kind must not be used. It is best to guard against the purchase of such defective mixtures by obtaining flux powders from reliable sources.

It is necessary that the welder learn to apply flux properly. An excess will cause as much trouble as an insufficient quantity. Blowholes may be increased in size and number by using too much flux. Also the molten iron will incorporate certain constituents of the flux if it is applied in excess. The amount to be applied depends upon the flux used. A welder must learn to know his flux as well as his blowpipe.

The powder should be applied regularly by dipping the hot welding rod into it. The quantity adhering is sufficient. Do not throw large quantites into the weld as plenty will be added by the welding rod.

Preparation of Welds. All cast iron over $\frac{1}{8}$ inch in thickness should be beveled or chamfered before welding. If this is not done, it is necessary that the metal be burned out by the blowpipe in order that complete penetration be assured. This is bad practice as it is almost impossible to do it without either changing the state of the metal in the groove due to the forced flame, or causing partial adhesion. The chamfering should be a little wider than on other metals for the reason that it is good practice to introduce as much special metal from the welding rod as possible.

The chamfering can be done by various means. If the casting is light and broken in two pieces, it may be taken to an emery wheel and the edges ground off. If the casting is too heavy to move, a portable grinder or cold chisel and air or hand hammer can be used. If the casting is only cracked, the cold chisel and air or hand hammer are the most satisfactory tools to use.

After the weld has been beveled satisfactorily, the adjacent metals should be cleaned about $\frac{1}{4}$ to $\frac{1}{2}$ inch from the edge. This is important, because all dust, sand, scale, etc., should be removed from the welding zone.

To Prevent Crack from Extending. If the defect in a casting is a crack that shows a tendency to extend upon heating, a hole should be drilled in the casting a short distance from the end and in the direction the crack would follow. The crack will not extend beyond this hole, and the hole can be very easily filled in.

Welding Process. Although the melting point of cast iron is not high, the total heat required to bring it to fusion is great, therefore a blowpipe of large size is used. The speed of welding is increased considerably, and the selection of the proper size blowpipe is influenced by the extent of the pre-heating.

Cast iron melts very rapidly after the fusing point is once reached, and when molten is extremely fluid. Because of this property, the welding should be carried on horizontally, otherwise the metal will flow toward the lowest point. This is not desired, because it will tend to produce adhesion. In case it is not possible to arrange the casting so that the weld will be horizontal, the welding must be started at the lower end, and skill must be used to prevent the too rapid advance of the molten metal. It is very difficult to produce vertical and overhead welds because of the fluidity. In welding thin sections of cast iron, the rapidity with which it melts and its fluidity often cause the metal to sink, bulge downward, or drop in. Consequently, it is necessary that close observation and careful manipulation be used on this kind of work.

Flame. The incandescent jet of the oxy-acetylene flame should never impinge on the molten metal. The tip of this jet should be held at a distance of $\frac{1}{8}$ to $\frac{1}{2}$ inch from the metal according to the thickness. The molten iron is seriously influenced by the high temperature of this jet and may become oxidized and decarbonized. This must be rigidly observed except when it is necessary to use the jet to burn out sand holes, blowholes, etc.

Manipulation of Blowpipes and Welding Rods. Because cast iron fuses rapidly when once the melting point is approached and the molten iron is extremely fluid, the circular or oscillating motion imparted to the blowpipe need not be so pronounced. The welding of cast iron is nothing but a succession of overlapping miniature pools, or puddles, of molten metal.

The weld is started by playing the blowpipe on the two lower edges of the weld. The flame should strike the weld almost perpendicularly, because if the blowpipe is inclined, the flame will blow the molten metal ahead of the weld, and adhesion will result. When at the proper temperature, these edges are fused together without any filling material by the aid of a little flux. It is important that this first operation be carefully carried out, as the strength of the weld is dependent upon a good bottom and top. When this first fusion has been successfully obtained, the welding rod is brought into play and the high silicon metal is added. With each addition, the welding rod is previously dipped into the flux can, and the adhering flux introduced in the weld, Fig. 73. As the welding of cast iron is a comparatively rapid procedure, the welding rod can be held more vertically and added faster, Fig. 74. In welding "dirty" iron it is sometimes convenient to hold the rod in a horizontal position and scrape out sand. carbon, or any other dirt by means of the rod

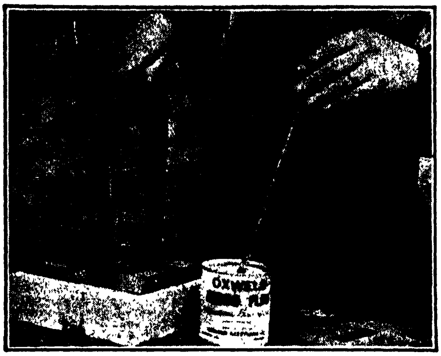


Fig. 73. Warm Welding Rod Is Dipped into the Flux before Each Addition to the Weld

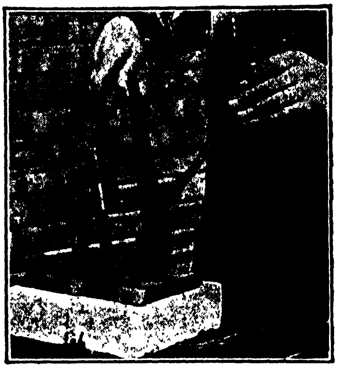


Fig. 74. For Cast-Iron Welding, Blowpipe and Welding Rod Are Held Almost Vertical

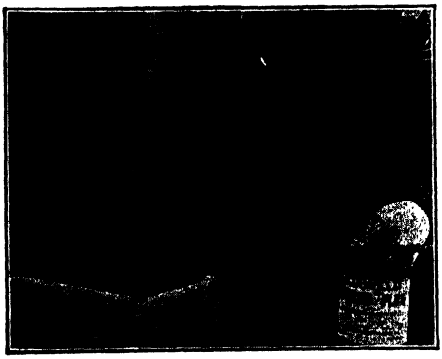


Fig. 75. Dirt May Be Scraped off by Means of the Welding Rod

Fig. 76. Welding Rod Should Not Be Held Too Far from Welding Zone.

as soon as it appears, Fig. 75. In this connection, it may be added that the welding rod should be used constantly to work out impurities and blowholes. The welding rod should be melted as much as possible in the molten metal of the weld. It should be plunged into this liquid, and the fusion carried out by playing the flame around it. The welding rod should not be held too far from the welding zone, Fig. 76, nor should it be added to the weld drop by drop as shown in Fig. 77.

As a section of the weld is finished, it should be scraped or rubbed with a file while red hot, Fig. 78, to remove the film of flux, scale, sand, and dust that is present. This film if allowed to cool becomes very hard and is quite resistant to machine tools. Regardless of the quality of metal beneath it, many welds have been rejected because of the hardness of this superficial surface.

Fig. 77. Welding-Rod Should Not Be Added Drop by Drop

Fig. 78. Scraping Finished Weld with File to Remove Scale

If the weld is carefully executed and the surface is cleaned, it will look like the left of Fig. 79, while if poorly executed and not cleaned, it will look like the right of Fig. 79.

Never go over a weld the second time if it can be avoided. In case it is absolutely necessary, always add fresh metal from the welding rod, as a failure to do this will cause a loss of silicon in the weld and destroy its value to the metal.

Always perform the welding as fast as possible, because extended heating will tend to lower the silicon content of the weld, with the resultant formation of hard iron.

Blowholes. Blowholes occur frequently in the weld and are particularly troublesome if in the bottom of the weld. Their presence can be caused by mechanically enclosed gases or by improper blowpipe handling. When blowholes appear in the weld, they should be instantly worked out. This may be done by forcing with the welding rod and applying flux. In beginning a weld, it is necessary that the presence of blowholes be guarded against, as it is difficult to work out a blowhole at the bottom of the weld after it is finished. Occasionally, in going over a weld, a blowhole is discovered; this must first be burned out by the white jet of the flame and then worked over with the welding rod.

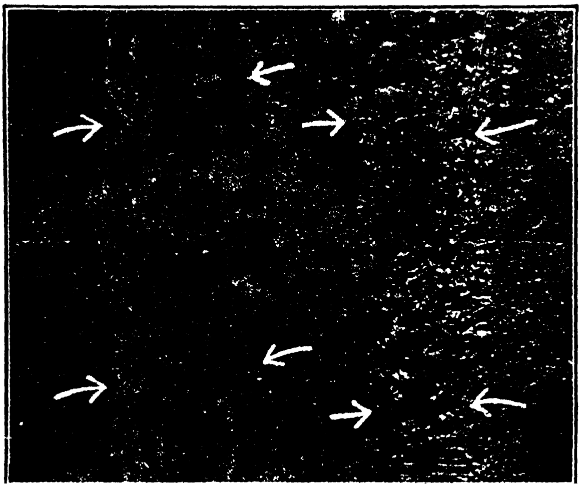


Fig. 79. Appearance of Cast-Iron Welds That Have Been Properly (left) and Poorly (right) Executed

After-Treatment. The rate of cooling materially influences the structure of the metal in the weld. If rapid cooling is allowed, hard brittle iron is produced. If slow cooling is employed, soft gray iron is formed. Internal strains and stresses may be distributed and adjusted or, in some cases, eliminated by proper cooling and annealing.

Castings which are not large or which it has not been necessary to pre-heat extensively may be satisfactorily annealed by playing the blowpipe on the weld and surrounding metal until it is at a bright red heat. The heated portion is then covered with asbestos paper, cinders, or other nonconducting material that will retain the heat and protect the castings from air currents. For small castings, a barrel or bin of hydrated lime and fiber asbestos is recommended. This makes a convenient arrangement and is very satisfactory as an annealing agent.

Where it is necessary to heat the entire casting in a charcoal or coke fire, the same temporary furnace used for pre-heating may be used in annealing. After the welding has been completed, the casting should be covered over with hot coals and ashes, and the furnace should be bricked up, i. e., all large air ports closed, the top covered with asbestos paper, and the casting allowed to cool with the fire.

The castings should never be removed from the annealing fire until they are entirely cold. This is imperative, as cold air currents on the warm castings may cause checks or cracks. In some cases, 12 to 24 hours are required for satisfactory cooling.

Use of Carbon Blocks. In case it is not possible to line up the weld horizontally, or it is necessary to fill in a wide hole, carbon blocks or steel plates are sometimes used to dam or retard the flow of the metal.

TABLE I
Properties of Metals

METAL	Weight Lb. per Cu. In.	Tensile Strength Lb. per Sq. In.	Melting Point Deg. F.	Relative Thermal Conductivity Copper = 1.00	Specific Heat	Coefficient of Linear Expansion	Approximate Expansion from 60° to Melting Point In. per Ft.
ALUMINUM							
Cast	0.093	15,000	1210	0.524	0.22	0.0000123	$\frac{11}{64}$
Drawn	0.098	24,000 to 40,000				0.0000136	$\frac{12}{64}$
BRASS							
Cast, Red	0.3103	20,000	1740	0.251	0.09	0.00000957	$\frac{12}{64}$
Cast, Yellow	0.2959	18,000		0.208			
Drawn		40,000 to 78,000				0.00001052	$\frac{14}{64}$
BRONZE							
Manganese	0.32	75,000 to 90,000	1692	0.735		0.00000986	$\frac{12}{64}$
Phosphor		50,000					
Tobin		60,000 to 100,000					
COPPER							
Cast		22,000	1980	1.00	0.095		
Drawn	0.3195	31,000				0.0000094	$\frac{14}{64}$
IRON							
Grey cast	0.2604	20,000	2190	0.124		0.00000556	$\frac{9}{64}$
White cast		18,000	2000				
Wrought	0.2779	55,000	2730	0.157	0.11	0.00000648	$\frac{12}{64}$
LEAD	0.411	1,780	620	0.091	0.03	0.0000155	$\frac{7}{64}$
NICKEL	0.312	76,000	2650	0.155	0.11	0.000007	$\frac{14}{64}$
STEEL							
Mild	0.283	50,000 to 75,000	2690	0.118	0.117	0.0000063	$\frac{12}{64}$
Hard		65,000 to 80,000	2570		0.1175		
ZINC	0.2526	5,500	785	0.29	0.09	0.0000144	$\frac{8}{64}$

OXY-ACETYLENE WELDING PRACTICE

PART III

MALLEABLE-IRON WELDING

Malleable Iron. Malleable cast iron, or malleable iron, as it is commonly called, is used extensively in castings where toughness, malleability, and resistance to sudden shock are required. The characteristic that gives malleable iron its greatest value as compared to gray iron is its ability to resist shocks. Malleability in a light casting, ¼ inch thick and less, means a soft pliable condition and the ability to withstand considerable distortion without fracture, while in the heavy section, ½ inch and over, it means the ability to resist shock without bending or breaking.

In the manufacture of malleable-iron parts, white iron castings are packed in annealing pots with suitable material, such as mill-scale, borings, etc., and subjected to a cherry red heat for from 48 to 96 hours, after which they are allowed to cool slowly. During this annealing process, the material in which the castings are packed absorbs the carbon from the surface of the casting. In this way the surface becomes really a steel, while the inside, or core, becomes gray cast iron.

Malleable iron is also used in cheap construction to take the place of steel forgings because of its cheapness. Malleable iron is strong on the surface only therefore it will not stand a great amount of machining and in this respect it resembles a steel forging.

Fusion Weld Not Possible. When malleable iron is heated to a fusing heat the malleable properties are destroyed and cannot be regained.

Brazing Malleable Iron. The most successful method of joining malleable iron with the oxy-acetylene blowpipe is by brazing with Tobin bronze. While this gives a joint of different color, yet the strength, malleability, and machining qualities are satisfactory.

The two pieces to be joined are beveled as for cast-iron welding.

The edges are brought to a point just below fusion, great care being taken that they *do not* become fused. When the edges are at the right temperature, a rod of Tobin bronze is fused into the groove with the aid of a good brass flux. A flux for welding malleable iron can be made by using borax in which is mixed a certain amount of brass filings. It is well at this point to state that the parts that are to be brazed should be perfectly clean and free from all grease. If the joint is to be machined or filed after the repair is made, it is a good plan to brush off the surplus borax just as the joint is cooling. The reason for doing this is because the borax when cold forms a glassy flint hard surface over the joint, which will rapidly dull any tool or file. A stiff steel brush is the best tool to use for the purpose of brushing off the surplus borax. The work should be carried out by using a flame having a slight excess of acetylene and should be done as rapidly as possible to prevent oxidation of the bronze.

ALUMINUM WELDING

General Considerations. When aluminum approaches its melting point, it does not change color in ordinary light, but retains its silvery appearance even when in the molten condition. It is very fluid and rather difficult to control under the welding flame.

Oxidation. Aluminum oxidizes very easily when in a molten condition, forming an oxide that melts at about 5400° F. The oxide, therefore, cannot be penetrated by means of the flame, but must be removed either chemically by means of a flux or mechanically by means of a paddle.

Expansion and Contraction. Because of the high heat conductivity of aluminum, expansion and contraction do not give great difficulty owing to localized heating. However, because aluminum expands greatly and is very weak when at high temperatures, contraction strains are very likely to produce cracks or checks unless the work is allowed to cool evenly and slowly. It is advisable to pre-heat aluminum castings to between 300° and 400° F. to aid the distribution of the heat and prevent warping.

Welding Rod. In welding sheet aluminum, such as automobile bodies, the welding rod should be clean material of the same alloy as the sheets that are being welded. If wire cannot be obtained of the same composition as the sheets, narrow strips should be sheared from the sheets themselves and used for a filling material. The strips should be sheared about as wide as the sheets are thick.

For aluminum castings, such as crank cases, a good grade of aluminum wire about $\frac{1}{4}$ inch in diameter should be obtained. Welders should not use the cheap solders or very low fusing cast rods that are sometimes sold, and for which great claims are made. The operator will readily appreciate that when these materials are added to the weld they will merely adhere to the sides, because, while the filling material will be quite fluid, the edges of the weld will not be at a fusing temperature.

Flux. It is impossible to weld sheet aluminum without the use of a good flux to dissolve the oxide and float it to the top as a slag. In cast-aluminum work a paddle may be used to accomplish this result, but such a device is not practical for sheet work. The flux may be applied either by dipping the warm welding rod into the flux powder or by mixing the flux with water to form a paste and applying this to the joints by means of a brush. Care must be taken that too much flux is not used, because an excess will produce a porous weld and one with a poor surface. After the work has been completed the flux should all be washed off with warm water.

Flame. In order to be sure that an oxidizing flame is not being used, it is permissible and advisable to use a flame showing a slight excess of acetylene. This flame will also have the advantages of being slightly larger in volume than the neutral flame and of lower temperature, this last feature being helpful, especially to the new operator.

Sheet-Aluminum Welding

Sheet-aluminum work may be handled very similarly to sheet steel as regards preparation and allowance for expansion and contraction.

Types of Joints. For light sheets under $\frac{1}{16}$ inch the flange weld should be used. The butt joint may be successfully made on light sheets by an experienced operator, but there is a great deal of danger of burning through and having to fill up holes, which will leave a poorly finished weld.

For sheets above $\frac{1}{16}$ inch the butt weld is found to be the best, and for sheets above $\frac{1}{8}$ inch the edges should be beveled the same as for steel plates.

Welding Process. Select the proper size blowpipe and welding rod, a good flux, and arrange the work for welding. Start the welding by playing the secondary flame of the blowpipe over the parts surrounding the weld, to warm them up slightly. If the flux is to be applied with a brush, it should be done at this time, because the heat will evaporate the water and leave the solid flux evenly distributed over the weld. Welding should then be started from ½ to 1 inch from the end—not at the end. The blow pipe should be handled about the same as for steel welding, care being taken that the inner cone of the flame does not come in contact with the metal. For very thin sheet welding it is not necessary to give the circular or oscillating motion to the blowpipe; it is merely necessary to move it forward in a straight line.

On the heavier work, however, the same motions should be used by the welding operator as are used for steel. The welding wire is best held directly in line with the weld and always in contact with the metal just ahead of the blowpipe. If the wire is not in contact with the edges when they become molten, they will be likely to curl up or draw away instead of flowing together. After the main weld has been completed, the operator should go back and weld the short section that was left unwelded at the very beginning. After the work has cooled the flux should be removed by washing off with warm water.

Re-Welding. The operator should be careful that the weld is completed as he goes along, so that he will not have to go back to make repairs or to do re-welding. If it is necessary to go back over a weld, cracks or checks are very likely to result because of the weak condition of the metal when it is at a fusing temperature. If it is necessary to re-weld a certain portion of the joint, the surface should be chipped off so as to present a clean surface for the new filling material to fuse to. Following the suggestions already made, the seam and the surrounding surfaces should be thoroughly preheated before the welding is started to prevent cracking as much as possible.

After-Treatment. If possible, welds in aluminum sheet should be reheated evenly to equalize any internal strains. Then, after the weld has become *cold,* it should be hammered to improve the grain of the metal.

Cast Aluminum Welding

Aluminum Castings. Most aluminum castings are alloys of aluminum, zinc, and copper; the alloy being added to the aluminum to give it a higher tensile strength and increase its resistance to shock. The welding of cast aluminum is different from that of sheet aluminum and resembles in a general way the welding of cast iron. Oxidation is taken care of by using flux or by scraping the oxide out by means of a paddle. The second method is faster and is the one preferred by most operators.

Paddle. The paddle is made by flattening down the end of a ¼-inch steel rod to a smooth short flat blade about ⅜ inch wide. The handle may be left straight or bent to suit the operator. The paddle should be used only when just below a red heat. If it is cold, the molten metal will stick to it, and if it is too hot it will burn and the metal will stick to the roughened surfaces.

Preparation. Sections if over ¼ inch in thickness should be chamfered before the welding is started. Sections thinner than this may be worked without beveling. The old metal may be scraped out by means of the paddle in order to give a clean bright surface for the new material to be added to.

Pre-Heating. Because aluminum alloy castings are not very ductile and are weak when at a high temperature, expansion and contraction must be taken care of. This is handled in the same general way as in the case of cast-iron work. The casting should be pre-heated either partially or wholly by some *slow* heating agent, such as a gas burner or mild charcoal fire. The pre-heating should never be carried to too high a temperature, because of the danger of the metal sinking, or caving in. The casting will be sufficiently warm for welding when a file or chisel will mark it easily, or when a piece of dry pine stick is charred upon being drawn across the heated section.

Welding Process. When a flux is used in welding cast aluminum, the work is carried on in the same general manner as in welding cast iron, and the same general precautions regarding the peculiarities of the metal are to be observed as in welding sheet aluminum.

If a paddle is used to break the film of oxide and scrape it out of the weld, the edges are brought to a state of fusion for a length of about 1 or 1½ inches. The paddle is then used to scrape out the weld to make a slight bevel and present clean surfaces for the filling material to be added to. The welding rod is then introduced into this groove. The paddle is used continually to work in the filling material, scrape off any oxide that forms, and then to smooth off the surface of the weld. After a small section of the joint has been completed, the casting is turned over, and the weld for this length is smoothed off on the underside by means of the blowpipe and paddle. The welding is carried on in this manner, section by section, until the entire joint is completed. If the weld were completed on the first side and then turned over and smoothed its entire length on the underside, cracks would develop, and the casting would warp out of shape.

After-Treatment. When the welding has been completed, the casting should be reheated slightly to remove any local strains and should then be covered over with asbestos paper to protect it from drafts and to allow it to cool very slowly. If the cooling is carried on rapidly, or if air currents are allowed to strike the casting, it will very likely crack either in the weld or some weak section.

COPPER WELDING

General Considerations. Because of the high thermal conductivity of copper, the heat from the blowpipe is conducted back into the work rapidly and is lost to the weld. This necessitates the use of a large size welding head or the use of an auxiliary source of heat to assist the welding flame in the case of heavy work. When at high temperatures, copper is weak in tensile strength the same as aluminum. Because of these two factors the effects of expansion and contraction must be carefully considered, so that the work will not cool too rapidly after the welding has been completed, and will not crack at high temperatures.

Oxidation. Copper oxidizes quite readily, forming an oxide which dissolves in the molten metal and changes the structure of the weld. The amount of oxide that can be absorbed is very high, consequently great care must be exercised to keep the absorption at a minimum. Welding rods containing a small percentage of phosphorus and suitable fluxes are used to counteract the oxide and reduce it as much as possible.

Welding Rod. For successful copper welding, it is necessary to use electrolytic copper containing about one per cent phosphorus, supplied in coils and drawn rods. The cast copper alloy rods that are on the market are not satisfactory, because the structure and composition will vary even in a single rod to such an extent that a homogeneous weld cannot be made.

Flux. In welding copper the flux is used not only to cleanse the weld, but also to protect the metal adjacent to the welding zone from the gases of the flame. When welding sheet copper it is advisable to make a paste of the flux by adding water and to coat the metal about one inch adjacent to the edge of the weld. When this flux is melted, it will form a glassy film that will protect the metal from the gases of the flame and the air surrounding the work. Additional flux is added to the weld as the work progresses, by dipping the warm rod into the dry flux, as in welding other materials.

Flame. It is very important that the neutral flame be maintained at all times, and the operator should use great care in adjusting his gases, so the flame will not have an excess of acetylene nor be oxidizing. Because of the peculiar properties of the metal, the gases of the reducing flame are very likely to be absorbed, and because of the ease with which the metal oxidizes, oxidation is liable to occur if the flame contains an excess of oxygen.

Preparation. Sheets that are less than $\frac{1}{8}$ inch in thickness may be butted together without beveling. Sheets heavier than this should always be beveled, and no attempt should be made to depend upon the flame to penetrate the heavier thicknesses. In all cases of copper welding, the edges to be joined and the material adjacent to the edges should be scraped or filed to present a clean surface for the filling material to be added to.

Welding. The edges of the metal surrounding the weld should be raised to a fairly high temperature before the actual welding is started. On small pieces and light-weight work, this may be done by means of the welding blowpipe, but for heavy work and long welds, it is best to do this by means of a gas or oil pre-heating burner. After the work has been brought to a high temperature, the welding should be started at one end and should be performed as rapidly as possible. The welding rod and edges of the weld should reach the state of fusion at the same time, so as to prevent adhesion and to insure a good weld. This feature is harder to accomplish in welding copper than in other metal, because the heat is conducted back into the rod or into the work very rapidly, necessitating very careful and skillful manipulation of the blowpipe and rod. The blowpipe should be held almost vertical, about the same as in the case of cast-iron welding. If held at too great an angle, the molten metal will be blown ahead and will adhere to the cold edges of the weld in advance of the blowpipe. The inner cone of the flame should never come in contact with the metal, but should be held about $\frac{1}{8}$ or $\frac{1}{4}$ inch above the surface of the weld to prevent burning the metal. The oscillating motion should be carried on about the same as in steel welding but a little more rapidly, and should consist of smaller circles. The welding rod should be plunged into the molten metal all the time and should be continuously moved around or stirred, so that it will be thoroughly incorporated and will bring the oxide and slag to the surface. The weld should be built up above the surface of the sheets, so there will be enough material to allow for hammering after the welding has been completed.

Re-Welding. In case it is necessary to re-weld a portion of the joint, it is necessary that the old material be chipped out and new material added.

After-Treatment. After the welding operation has been completed, the work should be heated very carefully and evenly until it is almost at a bright red heat. The weld should then be hammered while hot, so that the strength of the joint will be increased as much as possible. After the hammering has been finished, the work should be again reheated to a red heat and cooled quickly by means of an air blast or chilled by plunging in water. Care must be exercised in this operation if the work be a casting having confined, or rigid members, so that cracking, or checking, does not occur.

BRASS AND BRONZE WELDING

General Considerations. Brass and bronze are both alloys of copper, brass consisting mainly of copper and zinc, and bronze of copper and tin. Both brass and bronze are welded in about the same general manner as copper, but because of the peculiar properties of the alloying metals, zinc and tin, it is necessary that they receive certain variations in welding.

Oxidation. In both brass and bronze, the alloying metal is greatly affected by the high temperature of the flame, and the material will be subject to a loss of zinc or tin, unless proper precautions are taken. These metals will combine with the oxygen and pass off as white vapor, and leave a weld of different composition and color.

Absorption of Gases. The molten metal in both brass and bronze absorbs certain gases very readily, and unless this absorption is counteracted, the weld will be spongy and weak. This may be taken care of by using a suitable welding rod and flux.

Welding Rod. Because of the varying composition of brass and bronze, and because of the loss of the alloying elements when welding, it is practically impossible to produce welds of the same color as the original material. When welding brass, a good grade of drawn brass will be found most satisfactory, and in the case of bronze, a good drawn bronze, such as manganese or Tobin bronze. The cast rods that are on the market are not satisfactory, because it is quite impossible to cast a rod having the same composition throughout.

Flux. The flux used for brass and bronze is practically the same as that used for copper. It should be applied by dipping the warm welding rod into the powder and adding it to the weld in this manner. It is not necessary to use as much flux as in welding pure copper, and care must be taken that an excess is not used, because the weld may become porous.

Flame. A neutral flame must be maintained at all times for the same reasons as explained under copper welding. The blowpipe should be held between $\frac{1}{8}$ to $\frac{1}{4}$ inch from the metal. If the flame is held too close in the case of bronzes, the concentrated heat will cause a segregation or separation of the tin from the copper, and it will be practically impossible to again unite these elements.

Preparation. The edges of the metal for a thickness of less than $\frac{1}{8}$ inch may be merely butted together and welded, while for metals above this thickness the edges should be beveled or chamfered, so as to allow penetration of the flame and insure a good weld.

Welding. Because of the high conductivity of these materials, it is best that they be pre-heated to bring them to a suitable condition for rapid welding. Care must be taken when pre-heating bronze that it does not get too hot, because it is weak at high temperatures and is liable to break or crack under its own weight. The welding is carried on in about the same manner as for copper, and the blowpipe is handled in practically the same way. The welding rod should be in contact with the edges of the metal at all times, and the blowpipe should be played constantly on both the rod and the edges of the metal to keep them at the same temperature in order that adhesion may be prevented.

Re-Welding. Re-welding should be avoided, but if it is absolutely necessary to re-weld the work, the section should be chipped out, and new material added, as in the case of copper.

After-Treatment. Both brass and bronze should be annealed after welding by reheating evenly, and then allowed to cool slowly. Brass may be improved by hammering before the final annealing. Brass of low zinc content, i.e., red brass, should be hammered while hot, while brass of high zinc content, i.e., yellow brass, should be hammered cold.

MISCELLANEOUS PROCESSES

CUTTING

Cutting In Automobile Repairs. The oxy-acetylene cutting blowpipe finds considerable application in the automobile repair shop for beveling the ends of shafts and other pieces of work preparatory to welding, Figs. 80 and 81, cutting reinforcing plates out of large sheets for frame repairs, altering chassis, etc., Fig. 82. The cutting

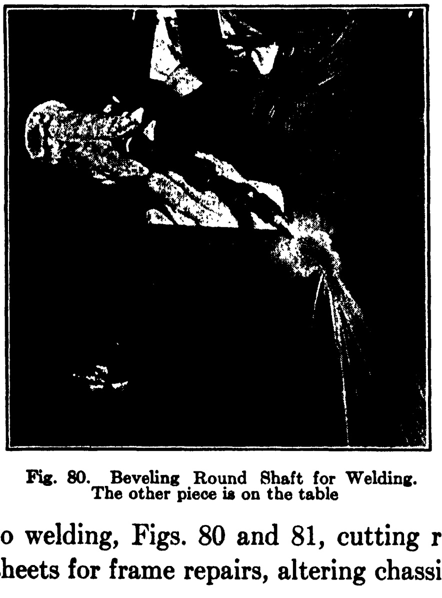


Fig. 80. Beveling Round Shaft for Welding. The other piece is on the table

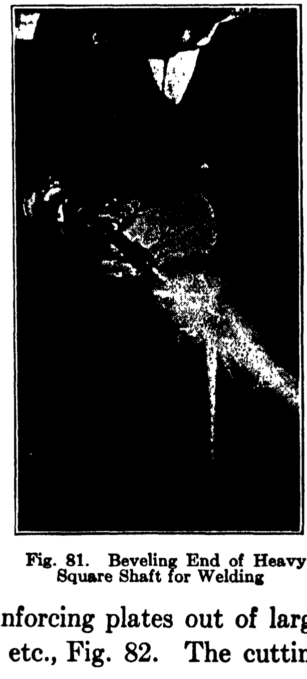


Fig. 81. Beveling End of Heavy Square Shaft for Welding

blowpipe is capable of doing this work cheaply and quickly, two necessary factors for the successful first-class repair shop.

Principle of Cutting with Oxygen. At ordinary temperatures, steel oxidizes in the air, forming what is commonly called "rust". At a white heat it will oxidize more rapidly, as is seen in the blacksmith shop when pieces are brought to a very high temperature. When steel is heated to a red heat, and a stream of pure oxygen is directed on it, the oxidation takes place more rapidly and more violently and is restricted to the locality upon which the stream of oxygen is played. This localized oxidation is the basis upon which the oxy-acetylene cutting blowpipe operates.

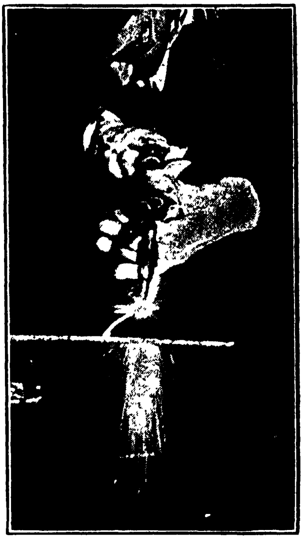


Fig. 82. Cutting Reinforcing Plate Out of Large Sheet Steel for Frame Repair

Metals That Can Be Cut. Steel and wrought iron are the only metals that can be cut successfully by means of the oxygen jet. Although cast iron, copper, brass, bronze, aluminum, etc., oxidize easily, nevertheless they cannot be cut.

When the oxygen combines with the iron, heat is generated. This heat of formation, with the aid of the heat supplied by the pre-heating flames of the blowpipe, brings the oxide to a molten condition. The molten oxide either flows or is blown out of the cut and leaves a fresh thoroughly heated line through the metal for the further action of the cutting oxygen. In the case of steel and wrought iron, the oxide melts at a much lower temperature than the material being cut and therefore blows out without melting the surface of the material. In the cases of cast iron and certain alloy steels, the melting temperature of the oxide is as high and in some cases higher than that of the metal, and therefore melts the edges or freezes in the kurf and so hinders the cutting. Also, in the case of some of these materials, the heat of formation produced by the combination of the oxygen with the metal is not sufficient to carry the cut through the thickness of the work.

Necessary Cutting Apparatus. A complete cutting station, Fig. 83, consists of the following apparatus:

Cutting blowpipe with set of cutting nozzles
Oxygen cutting regulator with two gages
Acetylene regulator with one or two gages
Adapter for acetylene cylinder
One length high-pressure rubber hose for acetylene
One length copper armoured hose for oxygen
Darkened spectacles, wrenches, hose clamps, etc.

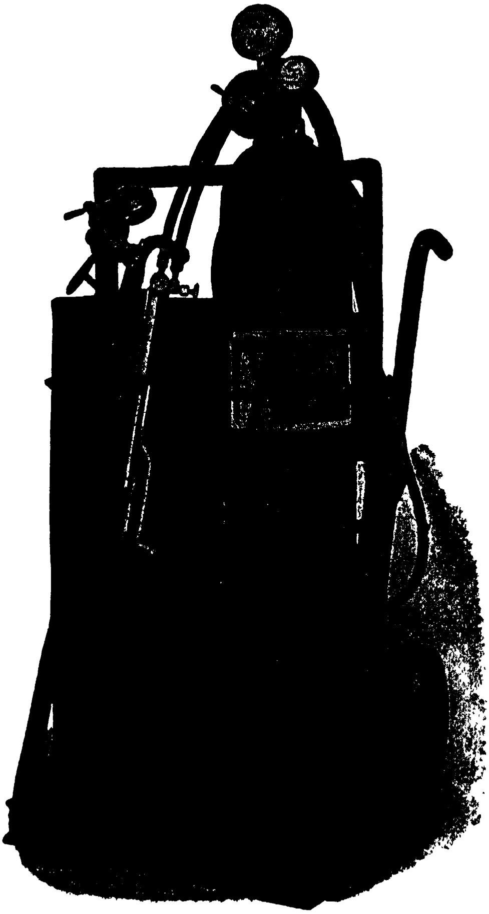


Fig. 83. Cutting Unit for Use with Acetylene in Cylinders, Mounted on Emergency Truck
Courtesy of Oxweld-Acetylene Company, Chicago

Cutting Blowpipe. In the cutting blowpipe, Fig. 9, page 9, Part I, there are six small oxy-acetylene flames surrounding a center orifice through which pure oxygen is directed. The six heating jets are used only for the purpose of bringing the edge of the material to a temperature at which the jet of pure oxygen will unite rapidly with the steel, as explained above.

Cutting Nozzle. There are usually four sizes of cutting nozzles furnished for handling work of various thicknesses, from very thin plate up to material 14 and 16 inches thick. Besides these, some manufacturers also furnish what is known as a "rivet cutting nozzle". This is a thin flat nozzle that can be laid against the sheet, allowing, the rivet head to be cut off close to the sheet.

Working Pressure. The necessary pressures of the gas that are required by the different sizes of cutting nozzles and for the different thicknesses of material are given by the manufacturers. It is very important that the operator use these pressures instead of higher pressures because of the increased amount of oxygen used and the consequent high cost of operation, also because the cut will not be smooth if too much oxygen is used.

Care of Blowpipe. If the blowpipe is handled properly there will be very little deterioration. It should only be necessary to clean the replaceable and working parts, repack the valves, and occasionally ream out and true up the nozzles. Care should be taken that the orifices of the nozzles do not become enlarged by reaming, because the heating jets will be made thicker and shorter and the cutting jet will spread rather than leave the blowpipe as a long thin stream.

The blowpipe may be cleaned the same as the welding blowpipe. Remove the acetylene and oxygen hose and connecting the nozzle to the oxygen hose, Fig. 16, page 18, Part I, and turn on the oxygen to a pressure of about 20 pounds per square inch, having first the cutting oxygen valve open, then the acetylene needle valve, and lastly the oxygen needle valve. This will allow the large particles to be blown out of the larger passages before they have a chance to clog up the smaller passages.

Regulators. The cutting regulator is the same as that described on page 20, Part I, but in size it is much larger than the welding regulator and is capable of both a higher delivery pressure and a greater volume.

The acetylene regulator is the same as is used in the welding equipment, and described on page 20, Part I.

Care of Apparatus. The blowpipe, regulators, and hose should receive the same care and attention as is explained for the welding apparatus on pages 18 to 21, Part I.

Instructions for Connecting Apparatus. The regulators and the blowpipe are connected up in the same manner as the welding apparatus, and therefore the operator is referred to pages 22 to 23, Part I, for instructions.

How to Light the Blowpipe. (1) Take the blowpipe in hand and open the oxygen cutting valve fully.

(2) Turn the oxygen pressure-adjusting screw to the right until the required pressure for the work to be done shows on the low-pressure gage. (See the maker's chart for the correct pressure.)

(3) Close the oxygen cutting valve.

(4) Open the acetylene needle valve fully.

(5) Turn the acetylene pressure-adjusting screw to the right until a good jet of acetylene issues from the heating orifices. In the case of pressure blowpipes, until the required pressure for the thickness to be cut shows on the low-pressure gage. (See the maker's chart for the correct pressure.)

6. Open the oxygen needle valve one-quarter turn and light the blowpipe by means of the pyro-lighter that is usually furnished.

NOTE—A back-fire might occur if there is not enough acetylene being supplied. If this occurs increase the acetylene supply by turning the acetylene pressure-adjusting screw farther to the right.

7. Adjust the acetylene pressure-adjusting screw to give a slight excess of acetylene to the flame.

8. Adjust the acetylene needle valve to give a neutral flame (see under Flame Regulation, page 25, Part I) when the cutting oxygen valve is open.

To Shut off the Blowpipe. In the case of the injector type of blowpipe, first close the acetylene needle valve and then the oxygen needle valve.

In the case of pressure blowpipes, first close the oxygen needle valve and then the acetylene needle valve.

To Cut. With the cutting valve closed apply the heating flames to the edge of the metal, keeping the nozzle at such a distance that the small flames barely touch the metal. As soon as the metal becomes heated to a cherry red, open the cutting valve, raise the blowpipe slightly to increase the distance between the nozzle and metal, and then move it along the surface as fast as a distinct and and clear kurf can be secured. The blowpipe should be held at a constant distance from the work. It should travel away from the operator in order that he may watch the cut advance.

Back-Firing. Occasionally, particles of molten metal will impinge on the nozzle of the blowpipe, or the operator will allow the nozzle to touch the surface of the metal, and the blowpipe will back-fire. When this occurs, first close the acetylene needle valve and allow oxygen to clear the passage, then open the acetylene needle valve fully and relight. If the back-firing continues, close both the acetylene and oxygen needle valves, cool the blowpipe by plunging in water and relight. Other causes of back-firing are loose internal and external nozzles or dirt on the nozzle seat. These can be eliminated by tightening the nozzles and cleaning the seat. These back-fires are usually only a series of pops or sharp reports, and, as a rule, will not extinguish the flame.

Notes on Cutting. *Heating Flames.* The heating flames should be small to produce smooth cutting. If the flames are too small, the blowpipe is liable to back-fire. If they are large, the top edges of the cut will melt and produce a rough cut.

Speed of Cutting. The speed of the blowpipe travel should be slow enough to allow the oxygen jet to penetrate yet not so slow that the oxygen will be wasted.

Restarting Cut. If the blowpipe travels too fast, and the cut is "lost", it is necessary to shut off the cutting oxygen and apply the heating flames to the point of stopping until the metal is hot enough to start the cut again.

To Cut Round Shafts, Etc. The cutting of round pieces will be made easier if the surface of the work is first chipped with a chisel. This will present a good edge for the cutting blowpipe to bite on.

To Pierce Holes. When piercing holes, a high oxygen pressure is necessary, and the metal must be brought to fusion before the cutting oxygen is employed. The blowpipe is held at a slight angle so the sparks will be blown out of the hole and away from the blowpipe.

Cutting Dirty and Poor Material. If there is considerable rust, scale, paint, etc., on the surface, the cutting will be interfered with by small particles flying against the end of the nozzle and perhaps causing back-firing. To overcome this, the heating flames may be made longer, allowing the blowpipe to be held farther away from the surface, or the scale or paint may be removed by first passing the flame over the line of cutting before the cutting is started.

LEAD BURNING

Different Methods. Formerly, lead burning, or lead welding, was confined to garages and service stations that catered to the electric automobile only, but since the introduction of electric lighting and starting batteries for gasoline automobiles, lead burning has become one of the works of the repair man in all garages. It is therefore important that the repair man have a sufficient knowledge of this class of work to enable him to handle any work of this nature that may happen to come into his shop.

Up to the time of the recent development of a very small oxy-acetylene blowpipe for lead-burning work, the hydrogen air burner was used by most lead burners. The oxy-acetylene blowpipe, however, is rapidly supplanting the old method and, as a matter of fact, within two years it has become universally accepted as being far superior to the old method in handiness of operation, speed, and consequent economy, and has been adopted by the large battery makers in both their factories and service stations.

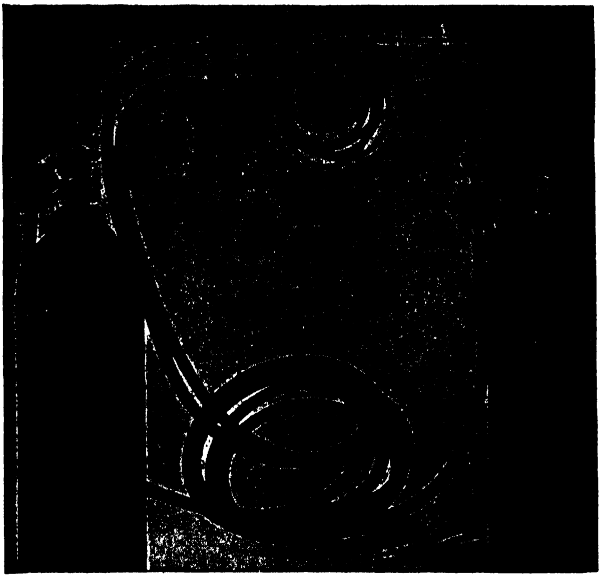


Fig. 84. Oxy-Acetylene Lead Burning Apparatus
Courtesy of Oxweld Acetylene Company, Chicago

When an operator accustomed to the old flame tries the oxy-acetylene blowpipe, he is very likely to discredit it at first and claim that it is not satisfactory. However, every operator who gives the oxy-acetylene lead-burning blowpipe a fair trial and uses it in accordance with the methods recommended by the manufacturers of the apparatus must acknowledge it as being superior to any method he has ever used. Its advantages are emphasized even move emphatically if he returns to the old, slower, and more costly methods.

Lead-Burning Apparatus. A complete lead-burning station for use with oxygen and acetylene, Fig. 84, consists of the following apparatus:

Lead-burning blowpipe with set of tips
Oxygen regulator with low-pressure gage
Acetylene regulator with low-pressure gage
Adapter for acetylene cylinder
Valve-block
Two lengths of high-pressure hose to connect regulators to valve block
Two lengths of small hose to connect blowpipe to valve block

Lead-Burning Blowpipe. To make the blowpipe as light in weight and as handy as possible there are no large valves. Instead, a valve block is furnished for regulating the gases, which may be attached to a bench or a wall. In order to make minor or finer adjustments of the flame, and to allow various size tips to be used on the blowpipe and still maintain a perfect flame, an adjustable injector is provided at the top of the blowpipe within reach of the operator's fingers.

Tips. There are about five sizes of tips supplied for use on different thicknesses and various classes of work, each giving its own special size flame. The oxygen consumption of the various size tips ranges from ½ to 6 cubic feet per hour. For storage-battery work the average consumption is about 2 cubic feet per hour.

Regulators. The regulators supplied with lead-burning apparatus operate on the same principle as the regulator described on page 19, the only difference being that they are of smaller size and especially adapted to small flames.

Operation of Lead-Burning Apparatus. The apparatus is connected in the same manner as the welding apparatus for which instructions are given on pages 22 to 26, Part I. The needle valves on the valve block are used to obtain approximate adjustment of the flame, and then the small thumb-nut on the blowpipe is used to make the finer adjustment. The pressure-adjusting screws should be set to give pressures of about 10 pounds per square inch for the oxygen, and 2 pounds per square inch for the acetylene.

The blowpipe, regulators, hose, etc., should receive the same care and attention as the welding apparatus and for which suggestions are given on pages 18 to 21, Part I.

Lead-Burning Process. The oxy-acetylene blowpipe should be handled in such a manner that the flame strikes the work perpendicularly. If the blowpipe is used on a slant, the inner cone will not bring the work to the fusing temperature as rapidly as if held vertically, and the secondary flame, or outer envelope, will be very likely to heat the surrounding metal to such a temperature that it will give way and break under its own weight. When working with the oxy-acetylene flame on storage batteries and the like, the operator should do the burning quickly. He should bring the flame down to the work, fuse the metal, add the necessary burning bar, or filling wire, smooth off the work, and remove the flame, all as rapidly as possible.

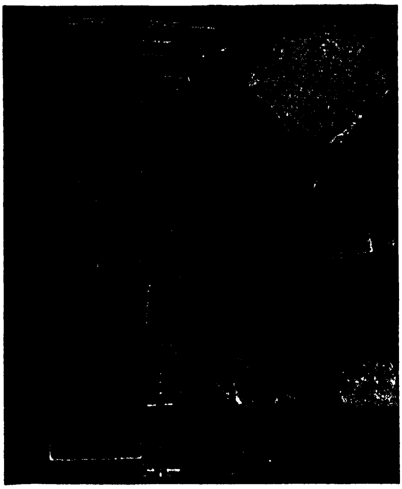


Fig. 85. Assembling Terminal Groups

Burning Terminal Groups. When burning plates to terminal bars, a small flame should be used, and the work should be held in a fixture, as shown in Fig. 85. The small ends on the plates should extend up into the terminal bar slots about two-thirds of the way. The burning should be carried on by first fusing the ends of the plates to the bottom of the slots, then filling up the rest of the slot by adding lead from a coil of wire or a burning bar. After the several plates have been burned on in this way, the flame should be moved perpendicularly over the surface to smooth it off and leave a nice finish. The flame should *not be held flat* against the work. It will take longer to smooth off the work, and it will not have nearly as neat an appearance if the flame is used flat.

Burning-On Connecting Links. The terminal poles should extend up into the links about one-third of the way. The flame should be brought down into the hole until the inner cone almost touches the top of the pole, and the pole fused and united with the bottom of the link as quickly as possible. After a good union has been secured in this manner, the burning bar should be introduced and the rest of the cavity filled up, Fig. 86. When working on links and poles it is advisable to do only part of one pole, move to another for a few minutes, and then come back to the first for a few minutes. This will allow the work to cool off slightly and will prevent breaking down or melting away. When burning this class of work, especially if the lead is old and pitted with dirt and cut by acid, it is advisable to increase the supply of oxygen and use an oxidizing flame when working down in the pocket. This will burn out any dirt and will prevent the blowpipe from puffing out when it is burning in the rare atmosphere that exists in the pocket.

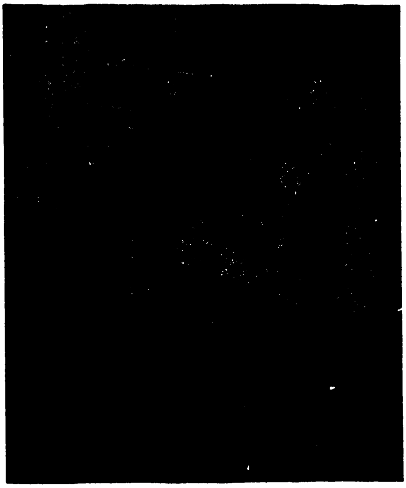


Fig. 86. Burning-On Connecting Links

Forms or Molds. Small steel frames, or molds, are found very convenient, especially when working on terminal links. These molds are shaped to conform to the work and are placed around it while burning. They are a great help in preventing the corners of the work from breaking down and melting away and, in this manner, relieve some of the tediousness of the work and allow the operator to work under less strain, and permit the work to be done by men who are not skilled lead burners, but who have occasional work of this sort to do.

CARBON REMOVING BY USE OF OXYGEN

Methods. *Old Process.* Up to within the last few years the methods used for removing the carbon from gas-engine cylinders were very impractical and unsatisfactory. To do this work meant the dismantling of the motor, the removal of all the parts, and the scraping of the cylinder walls by hand. Because this operation necessitated a great deal of work it was not done, in most cases, until the carbon deposit became very heavy.

Oxygen Process. The introduction of the inexpensive process of removing the carbon by burning it out by means of pure oxygen has replaced the old methods and they are no longer used. This new process is so simple, necessitates so little work, can be done so quickly and cheaply, that it can be employed every few months and, in that way, keep the cylinders free from carbon.

Carbon-Removing Apparatus. Complete apparatus for removing carbon by means of oxygen, Fig. 87, consists of the following:

Carbon-removing handle with flexible tube
Oxygen regulator with low-pressure gage
One length of high-pressure rubber hose

Fig. 87. Carbon-Removing Apparatus

It will be seen from this list that all that is necessary for a garage to have in addition to its welding equipment is the carbon-removing handle with a flexible tube.

Burning Out Carbon. Shut off the gasoline at the tank or just in front of the carburetor and allow the engine to run until it has sucked the gasoline out of the lines. Remove the valve caps and spark plugs from all the cylinders.

Turn the engine over by hand until the first piston is at the *upper end of its stroke* and both its *valves are closed.* Introduce a small quantity of kerosene into the cylinder head by means of an oil can or a piece of saturated waste. Light the kerosene in the cylinder, introduce the end of the flexible tube into the cylinder and allow the oxygen to play on the carbon at a pressure of about 5 pounds per square inch. The carbon deposit will catch fire and will continue to burn as long as there is carbon present. Of course, if the carbon is deposited in patches it will be necessary, after one patch has been removed, to start another by means of kerosene.

After the first cylinder has been thoroughly cleaned, turn the engine over by hand until the piston of the second cylinder is at its upper stroke with its valves closed, and then proceed to remove the carbon from this cylinder in the same manner.

After all the cylinders have been thoroughly cleaned, clean the valve caps and spark plugs by scraping or by burning off the carbon and then replace them in the engine.

Notes on Carbon Burning. Before burning out the carbon be sure that there is no chance of gasoline being present which might cause back-firing into the intake manifold.

The oxygen pressure should not be too high. Only enough oxygen should be supplied to keep the carbon kindled. Too much pressure will waste oxygen and increase the cost of burning out the carbon.

Too much kerosene must not be used, because there is a chance of the operator burning his hands with the sudden burst of flame that might result.

EXAMPLES OF AUTOMOBILE REPAIR

Pressed-Steel Parts. All pressed-steel parts of automobiles, such as frames, bodies, fenders, axle housings, tubing, etc., should be welded, using a pure iron welding wire for a filling material.

Frames. Almost all frame repairs necessitate a certain amount of dismantling of other parts. The extent of the dismantling depends upon the location of the proposed weld. If the work is to be done under the body, it is best to remove the car body. This is not absolutely necessary, however, because the work can be done by merely jacking up the body several inches to give enough room to do the work, and protect the body from the heat of the welding flame. If the weld is to be done close to the radiator, this should be removed so that the solder will not be melted out, Fig. 88. If the weld is about 12 inches from the radiator, the solder can be protected by placing sheet asbestos over the radiator. In this connection it is well to remind the operator that it is always advisable to cover the parts of the car near the welding with sheet asbestos to protect them from any possibility of the flame or heat getting too close.

Jacks should be placed under the frame and the frame brought into alignment before the welding is started; the jacks should not be removed until the weld has been completed and has become thoroughly cooled.

It is always advisable to bevel the work by chipping. In the case of frames of light-weight pleasure cars this may be dispensed with if the operator is careful to penetrate through the thickness of the material. All paint, dirt, and grease must be scraped off next to the weld from both the inside and outside of the frame before the welding is commenced, to prevent dirt from being incorporated in the weld.

A reinforcing plate should be prepared about the same thickness as the frame, as wide as the frame is high, and about three times as long as it is wide. This may be cut out of sheet steel by means of the cutting blowpipe, Fig. 82, page 79, or by means of a hack saw. The blowpipe is the quickest and easiest method, especially for cutting plates for curved frames such as are used on pleasure cars. The weld will look better if the reinforcing plate is welded on the inside of the frame, but in some cases that is impossible without a great deal of extra dismantling. It is then allowable to weld it on the outside.

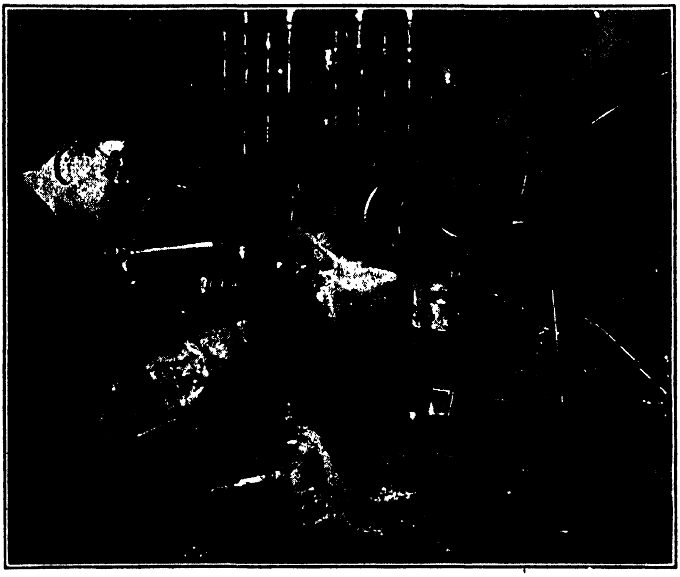
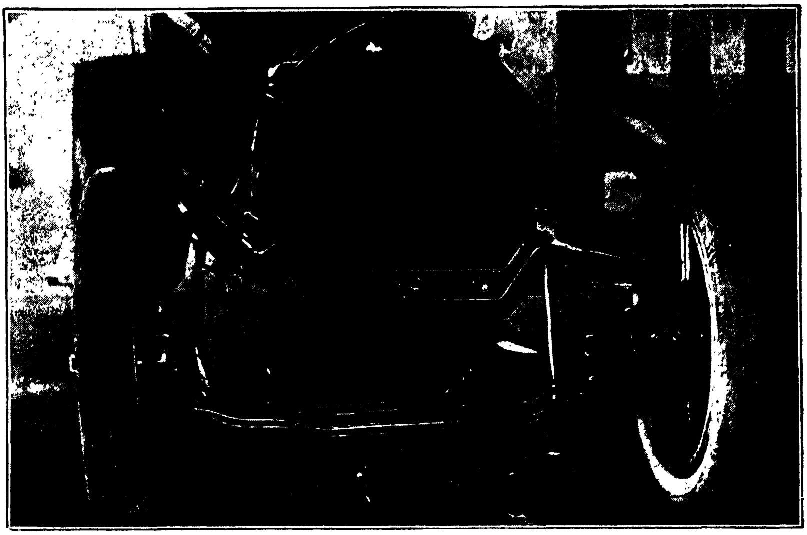


Fig. 88. Radiator Is Removed if Welding Flame Is Near It

The welding should start at the lower end of the frame and move upward as explained on page 31, Part I. The two flanges of the channel should then be welded, starting at the corner and moving toward the edge. When welding the lower



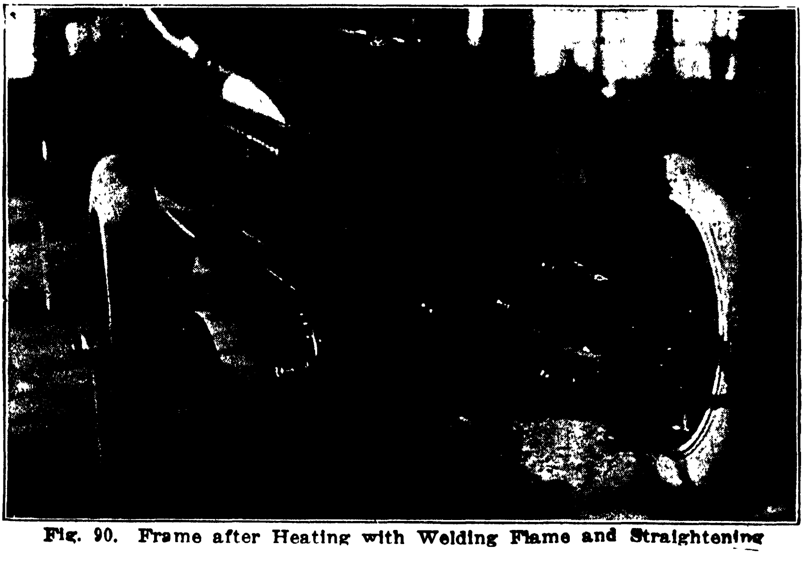


Fig. 90. Frame after Heating with Welding Flame and Straightening

flange, the work should be carried on as explained on page 31, Part I. After the frame has been welded, the reinforcing plate should be welded on by welding the horizontal edges first and the ends last.

The weld will be materially strengthened if it is hammered during the process of welding, as explained under Hammering, page 46, Part II.

The oxy-acetylene blowpipe is also very valuable in straightening frames that have become bent in accidents. A frame of this sort is shown before and after straightening in Figs. 89 and 90.

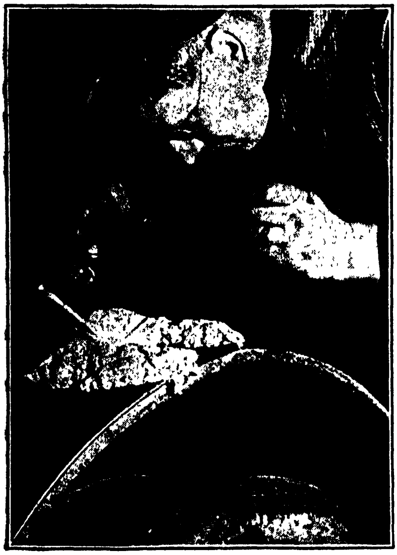


Fig. 91. Welding Torn Fender. Wet Asbestos along Weld Will Prevent Buckling of Light Sheets

Bodies and Fenders. Bodies and fenders that have been torn can be successfully welded if the operator uses his best efforts and is careful.

Fenders, as a rule, do not present very much difficulty because the break usually extends to the edge. It is advisable to pack wet asbestos along both sides of the weld to prevent buckling as much as possible, Fig. 91. The wet asbestos will absorb the heat and will not allow it to be conducted back into the sheet.

Bodies should be welded in a similar manner when they are torn. If possible, it is advisable to bend the edges outward slightly before welding. Then, as the weld is cooling, hammer it flat to compensate for the contraction that takes place.

If a patch must be welded in, it should be prepared either round or oval, or should have rounded corners of large radii. The patch should be dished to compensate for the contraction that will take place when the work cools. The hole in the body and the patch should be trimmed so as to fit well. When the patch is ready, it should be tacked in place. The welding should be carried on as quickly as possible. After the weld has been completed, the flame should be played on it to heat it evenly. As the weld starts to cool, the center of the patch should be heated

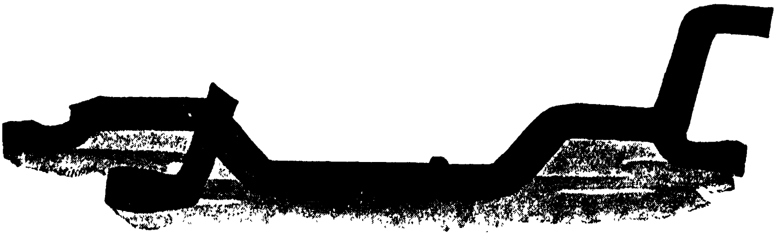


Fig. 92. Broken Front Axle

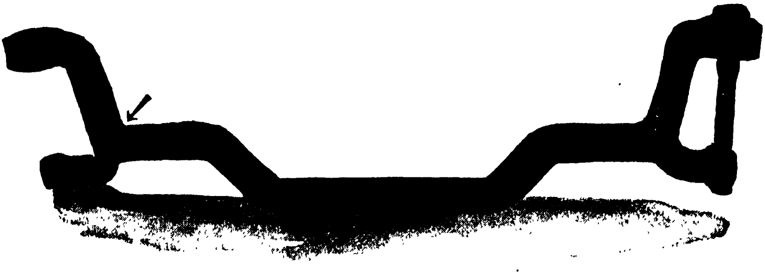


Fig. 93. Welded Front Axle

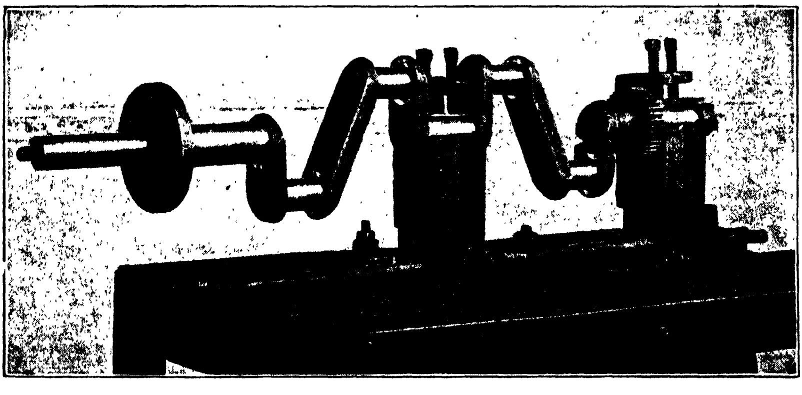


Fig. 94. Crankshaft in Crankshaft Jig Table for Welding

slightly so that it will stretch easily and compensate for the contraction taking place in the weld.

Springs. The welding of springs should not be attempted except for emergency repairs to allow the car to be used until a new spring can be obtained. A steel welding rod of low-carbon content should be used for filling material. No attempt should be made to re-temper the spring, because the average garage is not equipped to handle work of that nature and, consequently, the spring is very likely to be worse if a poor job of tempering is done than if tempering is not attempted. It is well to pack wet asbestos around the spring next to the weld to prevent the heat being conducted back into the rest of the spring.

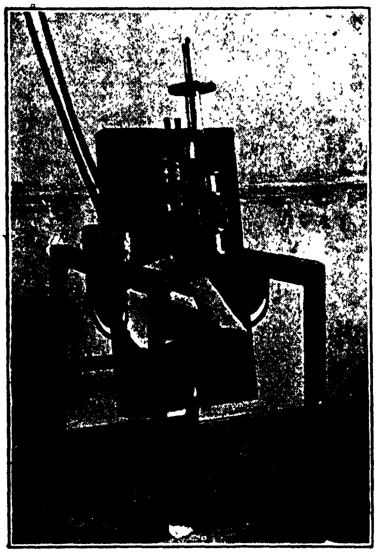


Fig. 95. Pre-Heating Crankshaft with Gas Burner

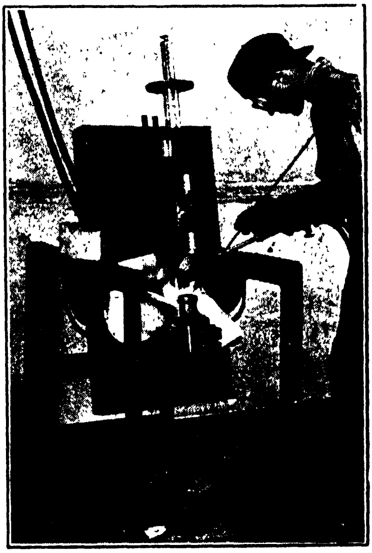


Fig. 96. Welding Crankshaft. Note that the Pre-Heating Burner Is Used to Assist the Welding Flame

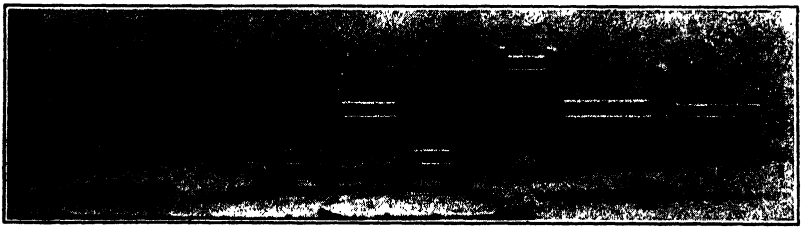


Fig. 97. Welded Crankshaft

Shafts and Axles. Shafts and axles are alloys of nickel, nickel and chromium, or chromium and vanadium. It is desirable to have the filling material of the same composition as the shaft or axle, but this is practically impossible. The most suitable welding rod that can be obtained for this work is one containing about 3.50 per cent nickel, or one containing about 0.20 per cent vanadium and 0.12 per cent chromium. This latter steel is more difficult to handle under the welding flame, so that most welders prefer the 3.50 per cent nickel rod.

Fig. 98. Broken Malleable-Iron Rear-Axle Housing

Square shafts, Figs. 92 and 93, and round shafts, Fig. 80, page 76, should both be beveled by means of the cutting blowpipe or by grinding, and should then be placed in alignment or in suitable jigs, Fig. 94. A gas or oil pre-heating burner should then be directed on the point of welding, Fig. 95, and the work heated to a red heat before welding is started. The welding should be done, Fig. 96, according to the instructions given under Welding Heavy Sections, page 58, Part II. After the welding has been completed the work should be reheated and any straightening done that is necessary.

Fig. 99. Repaired Malleable-Iron Rear-Axle Housing

The weld should then be heated up evenly, covered over with sheet asbestos, and allowed to cool slowly. The finished weld is shown in Fig. 97.

Axle Housings. If the housing is of pressed steel, it will not present any particular difficulty to the welder, except that he will have to take care that it does not get out of alignment. A pure iron welding wire should be used, and the work should be prepared and carried on as explained under Light Sheet-Steel Welding, pages 46 to 50, Part II.

If the housing is of malleable iron, Figs. 98 and 99, it should be beveled, placed in alignment, and then *brazed,* using Tobin bronze for a filling material as explained under Malleable-Iron Welding, page 69. The work may be pre-heated slightly to relieve the effect of expansion and contraction, but must *not be heated above a dark red.* The operator must be very careful to not bring the malleable iron at the weld to too high a heat or its malleable properties will be destroyed and the housing will be weak.

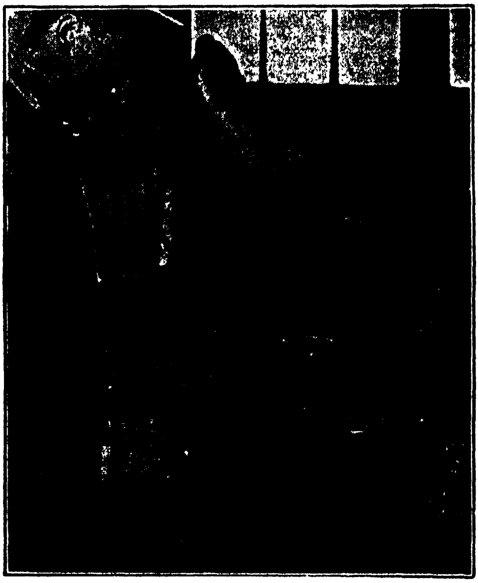


Fig. 100. Welding Broken Flange on Manifold

Manifolds. Pressed-steel manifolds should be welded according to the directions given, pages 46 to 50, Part II.

Cast-iron manifolds, as a rule, have only simple breaks to be repaired, such as broken flanges, Fig. 100. These should be beveled, and the parts clamped to a flat surface to keep them straight. They should then be pre-heated in the vicinity of the weld by means of the welding blowpipe before the welding is started. After the weld is completed they should be reheated evenly and then covered over and allowed to cool slowly.

Engine Cylinders. If the water jacket is cracked, the crack should be chipped out and the surface of the casting next to the groove should be cleaned by scraping. If the cylinder is cracked in the head end, it will be necessary to cut away a section of the water jacket by drilling or sawing, Fig. 101. After the cylinder head has been welded, the water-jacket section can be welded back into place, Fig. 102. Sometimes it is quite difficult to detect how far the crack really extends, therefore, care must be taken to be sure that it is chipped out its entire length.

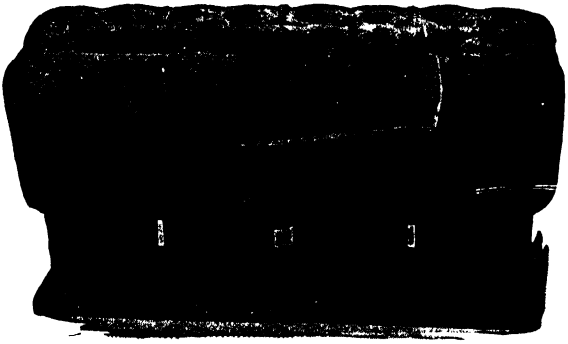


Fig. 101. Water Jacket Cut Away to Allow for Welding Cylinder Wall

All of the plugs and other fittings must be removed from the cylinders before pre-heating. The cylinders should be placed in the pre-heating fire with the open end of the cylinder upward, Fig. 103. They may be placed on a slant if the crack is on the side of the water jacket; but they must be in such a position so there

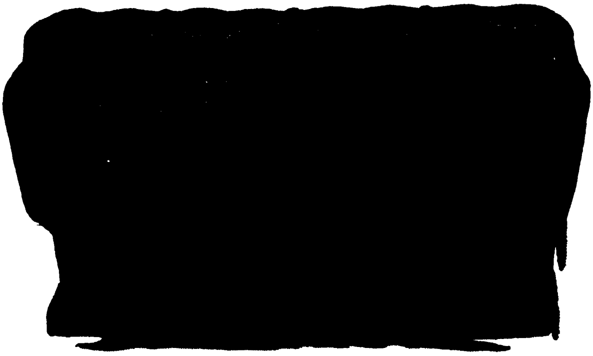


Fig. 102. Cylinder Wall Welded and Section of Water-Jacket Replaced

will be no chance for dead air to remain in them. If this precaution is not taken, the cylinder walls are very likely to crack.

The welding should be done according to directions given under Cast-Iron Welding, pages 59 to 67, Part II. The cylinders must be left in the charcoal fire all during the welding. It is even advisable to keep the top of the fire covered over and to weld through a hole in the asbestos paper, Fig. 103, to prevent air currents from striking the cylinder while it is hot. After the welding has been completed, the fire should be started up enough to heat the entire casting evenly, and should then be covered over and allowed to die out. The cylinder must not be removed until it has become cold enough to be handled with bare hands.

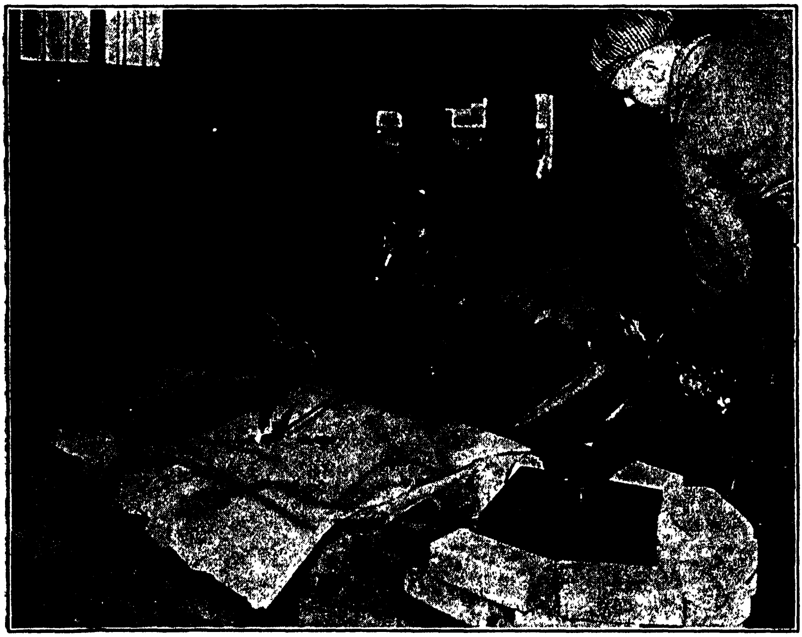


Fig. 103. Welding Cylinders and Preparing Pre-Heating Fire for Cylinders

Protection for Machined Surfaces. The finish in the bore of the cylinder will be affected by the heating if some means is not used to protect it. The best protection that can be used is to coat it and other machined surfaces with flaked graphite and oil. This can be made into a paste and painted on, or the surfaces can be oiled and the graphite dusted on. The latter method is really the best if carefully applied. The graphite must be coarse; the fine flake will not do.

Testing Welded Cylinders. There are several ways of testing welded cylinders. The two most generally used are by water pressure and by gasoline. In the first method, the water jacket is tightly plugged, filled with water, and then subjected to pressure by means of a hand pump. The method of using gasoline is simpler and quicker. The water jacket is plugged and filled with gasoline, Fig. 104. If there are any cracks or leaks the gasoline will work its way through and will spread out over the surface surrounding the crack or leak.

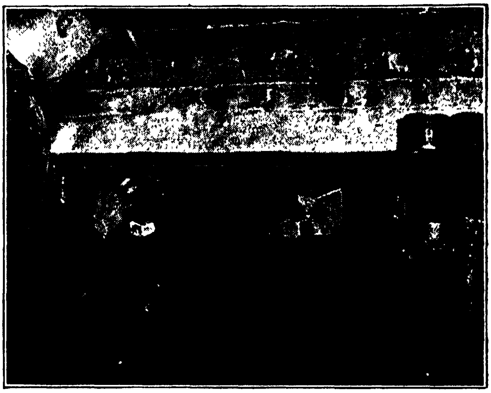


Fig. 104. Water Jacket Plugged and Welds Being Tested with Gasoline

Fig. 105. Welding Arm of Crankcase without Dismantling

Crankcases and Transmission Cases. It is usually necessary to remove the case from the car. But, if the arm is broken some distance from the main case, it may be welded while in position, as shown in Fig. 105. When welding in this manner, it is necessary to cover the parts near the welding with asbestos sheets to protect them from the flame of the blowpipe. The arm should be pre-heated slightly by means of the welding blowpipe before the actual welding is started, and, after the welding has been completed, it should be reheated to relieve any internal strains, and must then be covered over to allow it to cool slowly.

Fig. 106. Badly Broken Transmission Case—Must Be Pre-Heated All Over

Some operators spend a great deal of time trying to keep the bearing of the case in line, and while doing this they allow the rest of the case to twist, so that it is necessary to take a machine cut off the edges in order that they may fit the other half of the case. It is much better to keep the edges true and dress up the bearings, because it is quite likely that the bearings will have to be trued up anyway. The case should be clamped flat against two straightedges, but not too tight, or the case might crack from the strains produced when heat is applied. The case should be placed on the welding table in such a position that the welder can work on the outside and smooth off the inside without having to disturb its position.

Fig. 107. Lower Half of Crankcase with Piece Broken Out—Must Be Entirely Pre-Heated

The most satisfactory method of pre-heating is to place a gas burner under the case and let it burn *without an air blast.* If an air blast is turned on, the case is liable to become overheated and

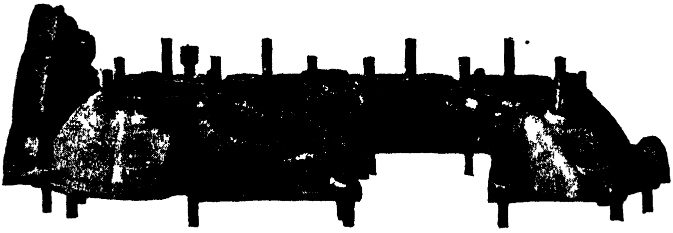


Fig. 108. Upper Half of Crankcase with Piece Broken Out and Missing

cave in. In fact, unless there are holes to allow some of the heat to escape, the case is liable to become overheated with only the soft gas flame. If the case is broken at one end, as shown in Fig. 108, it is only necessary to heat the one end; but it is very necessary to heat both sides of that end to prevent warping. If like the case shown in Figs. 106 or 107, it is best to heat the entire case. This can best be done by using two gas burners so that the heat will surely spread.

If the case is cracked or a piece is broken off, the welding should start at the inner end of the crack and move toward the edge or corner. The welding should be carried on as directed under Cast Aluminum Welding, page 73.

If a piece has been broken out and lost necessitating building up a section of the casting, Fig. 108, it is necessary to back-up the work by means of a piece of sheet iron bent to the required shape, Fig. 109. The welding should be started at one edge and should move across the space in a line parallel to the edge. When the added material gets almost to the opposite edge, the welding should stop, the edge of the case and the edge of the new added section should be cleaned, and then the weld completed in the same manner as for welding up a crack, Fig. 110, as outlined above.

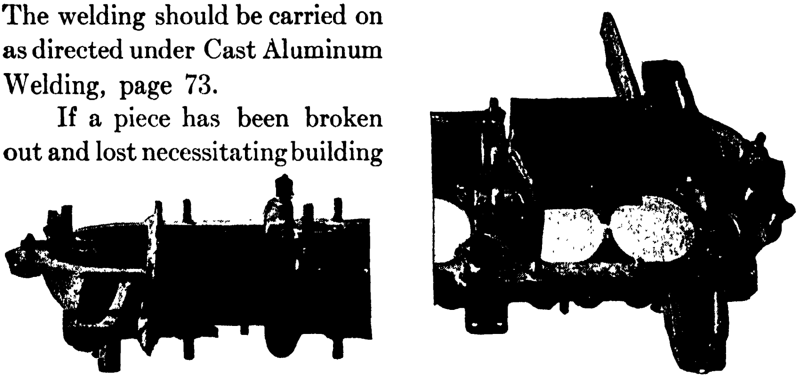


Fig. 109. Sheet-Iron Form to Back Up Section to Be Welded-In

COSTS

The cost of welding varies within wide limits for the different metals and the different classes of work. It is, therefore, not possible to give cost tables that will apply to all work. The costs given in Tables II and III are for steel work under fair conditions.

Measuring Oxygen Consumption. Oxygen is supplied compressed to 1800 pounds per square inch, in cylinders containing

TABLE II

Welding Cost Table

Thickness of Metal (in.)	Speed (ft. per hr.)	Oxygen per Linear Foot (cu. ft.)	Acetylene per Linear Foot (cu. ft.)	Cost per Linear Foot Labor.....45c Oxygen.... 2c Acetylene.. 2½c
$\frac{1}{64}$	26	0.15	0.14	$ .024
$\frac{1}{32}$	22	0.22	0.21	.030
$\frac{1}{16}$	17	0.43	0.41	.045
$\frac{3}{32}$	14	0.68	0.65	.063
$\frac{1}{8}$	11½	1.03	0.98	.083
$\frac{3}{16}$	9	1.84	1.74	.13
$\frac{1}{4}$	7	3.01	2.88	.20
$\frac{3}{8}$	4½	6.74	6.44	.40
$\frac{1}{2}$	3	13.2	12.5	.73
$\frac{3}{4}$	1½	38.7	37.0	2.00
1	1	76.7	72.9	3.81

TABLE III

Cutting Cost Table

Thickness of Metal (in.)	Speed (ft. per hr.)	Oxygen per Linear Foot (cu. ft.)	Acetylene per Linear Foot (cu. ft.)	Cost per Linear Foot Labor.....45c Oxygen.... 2c Acetylene.. 2½c
$\frac{1}{8}$	90	0.34	0.10	$ .014
$\frac{1}{4}$	74	0.55	0.17	.021
$\frac{1}{2}$	55	1.16	0.33	.040
$\frac{3}{4}$	46	1.91	0.47	.060
1	40	2.75	0.61	.082
1½	33	4.70	0.85	.13
2	29	6.97	1.06	.18
3	24	12.8	1.46	.30
4	20	19.4	1.96	.46
6	15	38.3	3.04	.87
8	11	69.7	4.60	1.55

TABLE IV

Factors for Correcting Oxygen Volumes

Deg. F.	Factor	Deg. F.	Factor	Deg. F.	Factor
100	0.929	75	0.972	50	1.020
95	0.937	70	0.981	45	1.030
90	0.946	65	0.990	40	1.040
85	0.954	60	1.000	35	1.051
80	0.963	55	1.010	30	1.061

100 and 200 cubic feet. The amount of oxygen in a cylinder can be measured quite accurately by means of the high-pressure gage on the regulator. Most of these gages are supplied with two rows

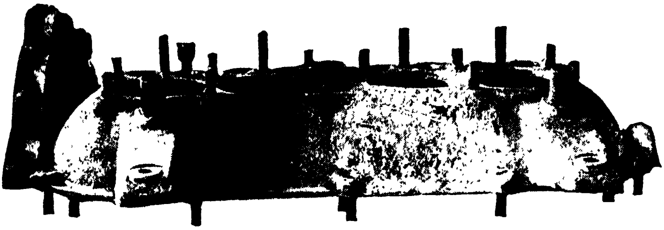


Fig. 110. Upper Half of Crankcase with Section Built-In

of figures on the dial, Fig. 111. The outer circle gives the pressure in the cylinder in pounds per square inch, and the other circle gives the per cent of oxygen remaining in the cylinder. The latter set of numbers makes the calculation very easy: e.g., if a 100-cubic foot cylinder is being used and the gage hand indicates 73, there is 73

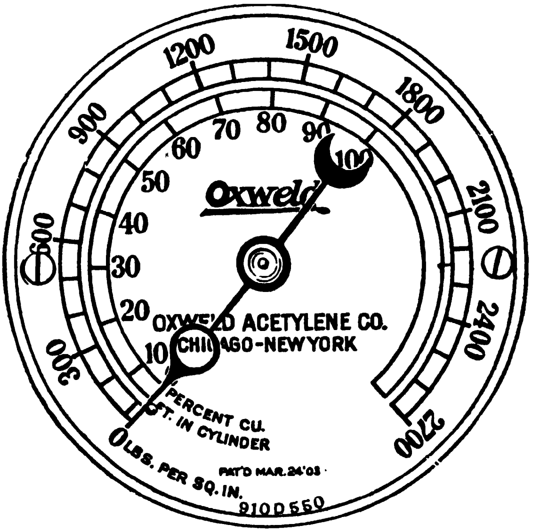


Fig. 111. Dial of High-Pressure Gage of Oxygen Regulator

cubic feet of oxygen in the cylinder. If a 200-cubic foot cylinder is being used, there is 200×0.73=146 cubic feet in the cylinder. The amount of oxygen indicated by the gage reading is more or less approximate and depends upon the temperature of the oxygen in the cylinder. The correction factors given in Table IV should be used to determine the volume of the oxygen at "standard temperature," 60° F., if an accurate measurement is required, e.g., if in the case given above the temperature is 50° F., then the real volume at standard temperature would be 146×1.020=148.9 cubic feet.

Measuring Acetylene Consumption. The amount of acetylene in a cylinder cannot be determined by means of the high-pressure gage. All the high-pressure gage can be used for, in the case of acetylene, is to indicate very roughly the amount of acetylene in the cylinder. There is only one method that can be used to determine the amount of acetylene used, and that is to weigh the cylinder. Each pound by weight of acetylene is equal to 14.5 cubic feet. Therefore, to determine the amount of acetylene used on a certain job, it is necessary to weigh the cylinder before and after welding and calculate the volume of acetylene used from the difference in weight, e.g., if the cylinder weighs 217 pounds before welding and 207½ pounds after welding, then $(217-207\frac{1}{2})\times 14.5=9\frac{1}{2}\times 14.5=137.7$ cubic feet.

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